# The Engineer

FEBRUARY 22, 1957 28 ESSEX ST., STRAND, LONDON, W.C.2 TWO SHILLINGS



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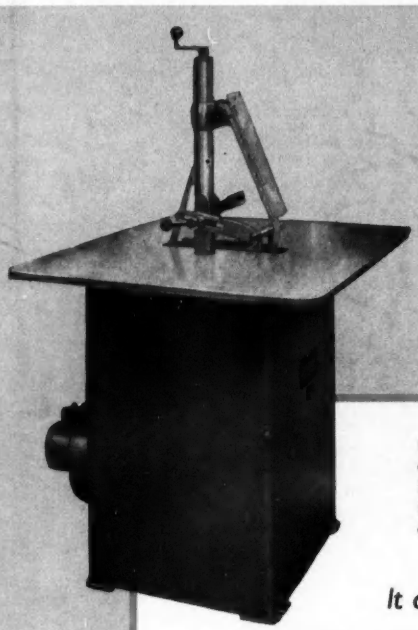

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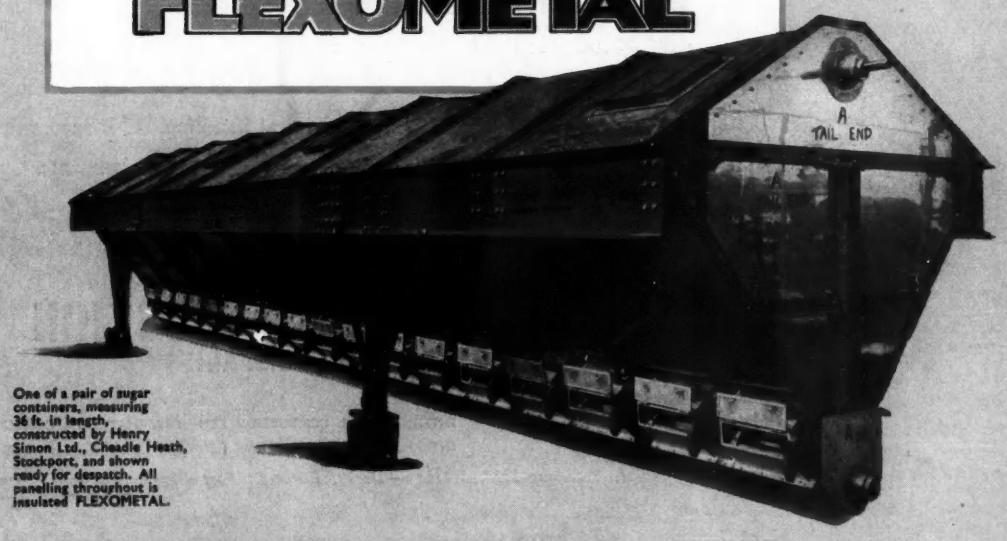


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# THE ENGINEER

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## FIGHTER POLICY

The Royal Aeronautical Society gathered in strength last week to hear a paper on "The Fairey Delta 2." While all of the members have doubtless taken a lively interest in the achievements of this aircraft since it appeared in public at Farnborough in 1955, there must have been many to whom the early history of it came as a surprise. Mr. R. L. Lickley's account of it appears elsewhere in this issue; he recalls that the aerodynamic design of the aircraft dates from 1949, although a contract for two machines was not placed until October, 1950. "Super-priority" work on the "Gannet" delayed a start on the research aircraft until the summer of 1952, and manufacture began about the end of that year. The first aircraft flew in October, 1954, exceeded Mach 1 a year later, and, as is well known, averaged a true speed of 1132 m.p.h. in two directions in March last year.

This history, so casually recorded in the lecture, will certainly lead to much debate and even controversy. The Convair "XF-92," pioneer of the thin-winged tailless deltas, first flew in September, 1948, and very little information about it and other United States research aircraft was available in this country before the "F.D.2" proposal was completed in 1949, so we see that the aircraft which to-day holds the absolute speed record can claim to be one of the earliest designs of tailless deltas. When we consider how rapidly the performance of aircraft is increasing (the "F-100" fighter, previous holder of the record, made its first flight only as early as May, 1953) this is a remarkable tribute to the design. Even more noteworthy is the interval that elapsed between design and construction, for when we recollect how much delay and difficulty have been experienced in developing warplanes of extreme performance in this country, the lapse of ten months before a contract was placed becomes, at least, intriguing. It is also surprising that, in a country with over a dozen aircraft constructors—not all, admittedly, independent—the need to produce a deck-landing, turbo-prop submarine killer should hold back the construction of a supersonic jet research aircraft. The rapidity with which the machine was built—"only very meagre and belated high-speed tunnel tests had been undertaken before the aircraft flew"—can be traced to the designer's selecting a configuration that posed the fewest or easiest problems and refusing to depart from it. The long time taken to achieve supersonic flight was due not to lack of "area rule," as in the contemporary "F-102" delta interceptor, but to the abandonment of mass balancing of the controls. Readers of THE ENGINEER will be tempted to observe that the one part of the programme which was carried through with appropriate expedition was the sheer hard engineering that culminated in July, 1954.

But gratification at our possession of the "Triple Crown" of speed records must not, however, blind us to the fact that, without doubt, the funds allotted to the "F.D.2" were intended to contribute to the defence of this country. It would be a fallacy to believe that research on supersonic, as distinct from hypersonic, flight is no longer necessary for military purposes. The fact that this country could be rendered uninhabitable by long-range bombardment with fusion warheads is no reason why it should be exposed to the far cheaper and more easily mounted attack of bombers with fission missiles. No one is in any doubt that military aircraft with flight speeds greater than the world record are in being to-day—Mr. L. P. Twiss made it clear that a record attempt is a test of ground control and observation techniques rather than sheer speed—and it follows that any fighter which is still in the prototype stage needs to be capable of high supersonic speeds. During the last twelve months a major group in the British aircraft industry found itself in a position to bring together a high-performance delta, a turbo-jet and a rocket motor cleared for flight. It can hardly be denied that, in the present state of international relations, a fully equipped fighter of superlative performance would be certain to find a customer. Yet the sponsors of this mixed-power-plant interceptor evolved in this country were prepared to abandon it. Possibly it was argued that as soon as a readily controllable rocket motor is achieved the aircraft should follow the example of the missile and cruise on a ram-jet, dispensing with the weight, temperature limitation and servicing problems presented by turbo-machinery. The much-maligned cancellation of the Miles "M-52" and the "little or no priority given" to the "F.D.2," appear to be the logical causes why there is a conspicuous absence of British combat aircraft matching American or even European performances. How marked is the deficit in this respect became clear to us the day after the meeting. Last year—early last year—the Solar Aircraft Company of San Diego gathered together seven producers of titanium and, pointing out that on the aircraft for which they were building components only titanium was equal to the duties involved, demanded better delivery and more consistent material. By contrast, last Friday, Imperial

Chemical Industries held a conference to ask the industry what use it was going to make of the increasingly large quantities of wrought metal available, and encountered a host of objections to the need for hot forming, the cost, and the numerous specifications in existence. Even Mr. Lickley's firm, it transpired, makes little or no use of titanium or its alloys. Where, we wonder, observing this history, are Britain's fighters to come from in the next few years? Can the "F.D.2," rapidly enough, be transformed? What is the defence policy?

### RE-RATING OF INDUSTRY

The decision of the Government, announced in Parliament last week, that industry and freight transport are to be re-rated to 50 per cent of the net annual value instead of the present 25 per cent, is decidedly unwelcome. In appearance the decision has been taken as a part of the Government's laudable scheme to strengthen the autonomy of local authorities by increasing their financial independence. Specific governmental grants tied to particular projects are to be, in future, largely replaced by "general" grants which authorities will be able to expend in any way they think fit. But in that context the contribution to be raised from industry is small. At present it is estimated that local authorities in England and Wales receive £490 million from rates, £581 million from grants, and some £436 million from other sources. The increased yield of rates levied upon industry is very difficult to estimate at all precisely, but it is likely to lie between £20,000,000 and £30,000,000. The contribution towards making local authorities more independent of the National Exchequer is, in fact, relatively so small that only one conclusion seems tenable. The Government's decision has been taken primarily on political grounds.

Were the decision accompanied by a clear statement that the Government felt the de-rating of industry to be fully justified, it might be accepted with more equanimity. For, though no precise figure can be calculated, it is clear that, as compared with householders and those using commercial and shop premises, industrial properties make less demand upon the services that local authorities provide, both absolutely, as, for example, through the provision of their own fire services, and in relation to the space occupied. But, unfortunately, in doubling the effective rateable value of industry, the Government seems to have been influenced as much by a fear that any more extreme action would cause too much financial disturbance as by any conviction that de-rating by 50 per cent is a justifiable figure. Its calculation was based on finance rather than on principle; and it bore in mind that there has already been a large increase in industrial rates as a result of the revaluation of the various classes of ratepayers. Of course, at a first glance, the new financial load that industry will be expected to bear does not look large. But, nevertheless, the effect may prove important. It can be contended of income tax—especially if it were borne only by distributed profits, which it is not, and supposing, which is untrue, that depreciation provisions were satisfactory—that it should have no effect upon costs or prices. But no such contention is tenable about rates. They are payable in bad years as well as good; they are overheads which cannot be avoided. Provision for them must be made in costs, and in certain industries finding competition in export markets hard to meet that provision may well prove embarrassing.

No doubt industry will welcome the Government's desire to give local authorities more autonomy as it may well lead to those authorities paying increased attention to the needs of local industry. But the cost is highly unwelcome. There is only one ray of light. Though revaluation for rating works with reasonable equity for householders and shops and even offices, it is difficult to apply to plant and machinery. Over the years many anomalies have arisen. Rating assessments are made according to rules that often produce peculiar results, as, for example, when an assessment increases largely because a new machine replacing an old one merely weighs more! One of the few satisfactory things about the Government's announcement is its stated intention, in consultation with industry, to review the rules by which the rateable values of plant and machinery are fixed. This review is to take place before re-rating takes effect. It is long overdue.

## The Engineer
## 100 Years Ago
(FEBRUARY 20, 1857)

"THE HYDRO-PNEUMATIC ENGINE"

"An interesting and valuable apparatus for organ blowing has just been fixed to the large organ at the East Parade Chapel, Leeds. The invention (which has been patented in England and France, by Mr. D. Joy, engineer, and Mr. W. Holt, organ builder, Leeds), is called the 'Hydro-pneumatic Engine,' and can be affixed to any organ. Its object is to supersede manual labour and the more expensive steam-power in blowing large organs in churches, chapels and public edifices; and its usefulness and economy are not more apparent than its compactness and simplicity. The apparatus in East Parade Chapel is affixed to an ordinary one inch pipe, conveying the town's water, brought into the vestry beneath the chapel. The whole apparatus does not occupy a space exceeding four feet, and it is found fully equal to blowing the bellows of the organ above, which is an instrument of forty-four stops, including pedal pipes of twenty-four feet to GGG.

"Upon turning the tap of the water-pipe, the apparatus is at once set in motion, and air forced into the bellows with the utmost regularity until they are properly filled. The engine then stops until the air is so far exhausted by the performer that the bellows have fallen an inch, when it re-commences pumping air into them until they are filled; and this goes on with a more or less rapidity—without any interference whatever—according to the exhaustion of the air by the player. The pressure is very much more steady and continuous than can be attained by manual labour. Near to the hand of the organist is placed a stop, by applying or removing which, by a touch of the finger, the apparatus is set in motion or stopped at once. The advantage of the invention is equally great in a pecuniary point of view. For example, at East Parade, £8 per annum has been paid to the organ-blower; but the apparatus has been fixed for less than £40, and the consumption of water is not more than 2¼d. per day, or less than 11s. per annum for the Sunday services. Probably, taking all the services in the year, the cost of water will not exceed 25s."

### TRAINING OF NAVAL ARCHITECTS

The challenge of many foreign countries to our supremacy in the art and practice of shipbuilding has steadily grown during this century. It is a startling fact that Japanese yards are building as large a tonnage annually as British. The holding of a symposium on "The Education and Training of Naval Architects and Marine Engineers" by the Institution of Naval Architects and the Institute of Marine Engineers on February 6 was, therefore, timely. The first of the five papers was presented by Professor E. V. Telfer. It was intentionally provocative and it took to task certain findings and recommendations of the 1939 Report of the Committee on the Education, Training and Employment of Youths and Apprentices for the Executive Grades of the Shipbuilding Industry. Professor Telfer drew attention to the rather remarkable fact that the British shipbuilding industry had never directly financed research scholarships in naval architecture; and he firmly rebutted the Committee's statement on the lack of benefits resulting to the industry from research scholarship holders, by referring to the positions now held by several of them. There is, however, a dearth of applicants for the Institution scholarships. Seeking reasons, Professor Telfer found them partly in the fact that hard study did not bring any immediate reward and partly in the rather low academic rating of the industry. He called particular attention to the disparity in numbers between the professors of naval architecture in this and other countries, despite our leading position as shipbuilders. The size of our industry, he thought, warranted an expansion of our schools of naval architecture from two to seven and the appointment of five new professors. Turning from schools to teaching methods, he suggested an international conference to examine pedagogical issues; and the institution of a loose-leaf tutorial system to improve the "putting-over-efficiency" of the teaching staff. On matters of research he felt that the present pattern should be extended to every shipyard so that all subjects could

be investigated to the eventual benefit of the whole of the industry.

Twenty years have elapsed since Mr. Lloyd Woollard presented a paper, "The Education and Training of Naval Architects," and within that period there has occurred a world war and a complete change in the shipbuilding industry from slump conditions to those of prosperity, with full order books and the prospect of full employment for many years ahead. This turn of fortune's wheel has tended to conceal the fact that the British industry is losing ground to those of other countries. Probably it is inevitable that the British share in tonnage under construction in the world should fall. But if leadership, at least in design, is to be retained it does seem desirable that more highly qualified men should be attracted to the industry. Fortunately, the prosperity of the industry has already attracted an increased number of students to the universities but the remedy for the lack of prospective scholarship holders needs new thinking within the industry about the status of graduates and the matter of their financial reward. It may very well be that the present system of awarding scholarships by local authorities affects entries for the Institution scholarships, but having offered the necessary subjects at "A" level there appears to be very little inducement to students to take a further selective examination. Furthermore, an examination of the monetary value of the scholarships in question reveals that few of them are now adequate to finance a student through his university training. As within the engineering industries in general, the need is beginning to be recognised, if adequate numbers of talented men are to be attracted to the industry, that boys at school (and their masters) must be better informed about the career and its prospects.

No doubt more men taking university courses suggests, as a prerequisite, additional centres of teaching, but how many new schools of naval architecture would be necessary is difficult to assess. However, any assessment of the numbers of professors required on a basis of tonnage output is hardly the yardstick which can be recommended. There is not necessarily at all a close connection. More graduates are not, of course, the universal panacea for the ills of shipbuilding, many of which can be traced to the fact that out of date union restrictive practices discourage attempts to make technological advances in construction methods. Yet an all-round improvement in the technical educational standard of those engaged in shipbuilding could not be anything but beneficial. Perhaps, like the delivery of Mr. Woollard's paper, the holding of the symposium will result in the formation of a committee to study the situation and make recommendations which will go far to set the industry's house in order.

# A Seven Day Journal

### National Institute for Research in Nuclear Science

IN a written Parliamentary reply, made last week by Mr. J. Enoch Powell, Financial Secretary to the Treasury, it was announced that the Government had decided to set up a National Institute for Research in Nuclear Science. The main object of the Institute, it was stated, would be to provide, for common use by universities and others, facilities and equipment which were beyond the scope of individual universities and institutions carrying out research in the nuclear field. It would not replace the research now being done in individual universities with assistance from Government funds; nor would it affect the Government's participation in the international scheme for common facilities in Geneva. In the Government's view, Mr. Powell stated, the Institute would satisfactorily fill a gap which would otherwise exist in this country's power to keep in the forefront of nuclear progress. The Government's proposal was that the Institute should be financed in the main by grants through the Atomic Energy Authority from the Lord President's atomic energy vote and provision would be taken in estimates accordingly. The universities' expenditure would be confined to the payment of the salaries and expenses of their own academic staffs utilising the research facilities provided. The reply added that the Institute would be managed by a governing board appointed jointly by the Lord President of the Council and the Chancellor of the Exchequer, and consisting of representatives of the universities, the Atomic Energy Authority, the University Grants Committee, the Royal Society, and the Department of Scientific and Industrial Research. Lord Bridges, it was stated, had accepted appointment as independent chairman of the governing board.

### Consultants' Annual Dinner

THE Association of Consulting Engineers held its annual dinner, at the Dorchester Hotel, London, on February 18. The principal speaker was Viscount Waverley, who proposed the toast to the Association. The Viscount spoke of the importance of engineers in the world of to-day, and went on to criticise the term "engineer," which, he pointed out, was lacking in precision. The absence of any specific connotation was a matter which, in his opinion, needed attention in the public interest; he referred to other professions—dentists, architects and now accountants—which had been faced with the problem of defining their profession. The professional engineer probably had a more difficult problem, he considered, which might be solved by better organisation and a wider understanding of his work. Viscount Waverley went on to speak of the work of the Association of Consulting Engineers; he noted that its membership had increased from 200 to 430 since the end of the war, and that the value of work in progress overseas, at the beginning of 1956, which members were supervising, stood at £430 million. However, work was also needed for consultants at home, he affirmed, and he particularly stressed his opinion that consultants should be active in the development of nuclear energy. Viscount Waverley's toast was followed by a reply from the Association's chairman, Mr. V. A. M. Robertson, who also spoke of the problem of professional nomenclature. He thought that a committee of the three major institutions might investigate that matter, and also education and publicity. Mr. J. S. Tritton proposed "The Guests," and Mr. D. Walker-Smith, Minister of State, Board of Trade, responded. Mr. Tritton referred to progress in agreeing international conditions of contract; as a result of five years' work, such conditions had recently been agreed by about a dozen countries and also the World Bank.

### Naval Nuclear Propulsion

A STATEMENT issued by the Admiralty has announced the creation of a new post, Rear-Admiral Nuclear Propulsion, to which Rear-Admiral G. A. M. Wilson, Deputy Engineer-in-Chief for Fleet Maintenance and Administration, has been appointed. He will also be Deputy Engineer-in-Chief (Nuclear Propulsion) and will generally direct the operations of the naval project team of the Atomic Energy Research Establishment at Harwell, where a considerable amount of work has already been carried out on the development of a nuclear power plant for a submarine. Rear-Admiral Wilson will form a link between the Admiralty and other Government departments as well as being the focal point within the Admiralty for all the various aspects in the development of this form of propulsion. Apart from the purely naval development of nuclear power plant for a submarine and other service ships, Admiral Wilson, it is stated, will keep in close touch with studies at present going forward concerning the application of this form of power to merchant ships. In making this appointment, the Admiralty stresses that it has expressed its faith in the early development of this form of power plant.

### Sir William Verdon Smith

WE record with regret the death last Tuesday of Sir William Verdon Smith, C.B.E., at the age of eighty. After losing his father when he was thirteen, he worked with his uncles in a stock-broking firm: on the death of one of them in 1916 he became managing director of Bristol Tramways. Soon after the Great War he extended the services into the surrounding country with motor buses. In 1927 he succeeded his other uncle as chairman of the Bristol Aeroplane Company, Ltd., and held that post until he retired in June, 1955. During this time the company expanded immensely: at the beginning of it the radial air-cooled aero-engine was adopted and, by applying the principle of the single valve sleeve to this, engines of high efficiency and long overhaul life were developed. The last Bristol piston engine, the eighteen-cylinder "Centaurus," is still in use for civil and military transport aircraft. The aircraft division of the company concentrated principally on military aircraft, and during the second world war produced numerous machines to its own designs: the "Beaufighter" is still in use with the Royal Air Force. After the war the company took up the manufacture of helicopters and of motor-cars: it also began to build civil aircraft, both a small passenger/freight machine and the largest British landplane to date, the "Brabazon." Utilising the free turbine engines which the company advocated from the first, passenger-carrying machines are now the main product. Sir William was knighted in 1946: he is survived by a son and daughter and his second wife.

# Engineering Problems in the Application of Nuclear Energy

By SIR CLAUDE D. GIBB, K.B.E., D.Sc., M.E., F.R.S.*

No. I

*Last Friday, February 15, at a meeting of the Institution of Mechanical Engineers, arranged in conjunction with the British Nuclear Energy Conference, the forty-third Thomas Hawksley lecture was delivered. It is reprinted here almost in full. The author first gives consideration to general matters having a bearing upon the design of a nuclear station intended primarily for the generation of base-load power and devotes the major part of the lecture to some of the principles that have influenced the design of the power station to be erected at Bradwell in Essex.*

So much has been spoken, written and published on the subject of nuclear energy that it is now well-known that a nuclear reactor is merely another source of heat capable of being harnessed to produce steam which, by means of a more or less orthodox turbo-generator, develops power in the form of electricity. The key to the industrial development of nuclear energy is the reactor and the means adopted to transfer the heat released during nuclear fission into the steam required to drive a steam turbine. It is not at present believed to be possible to generate power economically by nuclear fission except through the medium of the steam cycle and, since this lecture is to be concerned with engineering problems, it is not proposed to theorise on hypothetical reactors of the future.

Reactors available to-day may employ as fuel either natural or enriched uranium. The moderator, necessary in thermal reactors to slow down the neutrons and make them more effective may be graphite, heavy water or ordinary light water. Beryllium need not be considered at this stage since it is not available in quantity and is too costly for large-scale use. Light water demands some degree of enrichment for its fuel and the engineering problems are very great if it is to be used as a moderator for industrial large-scale power generation.

The essentials of any system for electricity generation are well-established and may be stated as :

(1) Reliability of the highest possible order with its consequential high availability of supply.

(2) Minimum cost per unit of electricity delivered for sale; this covers capital and fuel and maintenance costs per unit.

(3) Minimum of nuisance from smoke, dust, effluent, or other factor likely to cause opposition to the siting of the power station in a location most favourable for minimum transmission costs.

If the power station employs steam turbines then large quantities of condenser cooling water are required, but this condition must be met regardless of the fuel used.

The need for reliability is obvious since if there are doubts regarding the plant availability when power is required, then stand-by plant must be provided at increased capital cost which must be charged against the unreliable plant. This factor leads to a philosophy of design which must determine and dominate all stages of research, development and construction in nuclear as in orthodox power stations.

Safety is inherent in reliability and also will play an important part in deciding on the siting of a nuclear power station, since if there is any possibility of danger arising during its construction or operation there will be opposition to any site near a load or population centre, thus increasing transmission costs. Hence, the selection of Dounreay, in the far north of Scotland, for the siting of Britain's first large-scale fast-breeder reactor until it is known for certain that its many engineering problems have been solved with resulting absolute safety. The fast-breeder reactor may be considered to be the ideal reactor offering the greatest fuel economy at present envisaged and, after many years of development, may well play a major part in future industrial nuclear power. It is not, however, at present available for use in Britain's urgent need.

Enriched uranium is not available at present and, while the international situation remains unsettled, will not be available in quantity for industrial purposes. In any case, enriched uranium is what Sir Christopher Hinton has rightly called it, namely, " potted electricity," since the major cost item in its production is that of the electrical power used to drive the compressors in the diffusion plant. Since electricity costs are higher in Britain than in the United States of America and Russia because of higher coal and oil costs, it is obvious that British produced enriched uranium would not be competitive in world markets as a fuel. Thus, because enriched uranium has not been, and is not now, available, the British nuclear power programme had perforce to be based upon natural uranium as the fuel. Perhaps we were fortunate in this respect since the field of research and design was narrowed and diversity of effort thereby avoided.

Similarly, with considerations of using heavy water as a moderator. Thinking only in terms of neutron economy—and this is very necessary with natural uranium as the fuel—heavy water is an excellent moderator, superior to, but costing some one hundred times as much as, graphite which was available readily whereas heavy water was not. A major cost item in the preparation of heavy water again is the considerable amount of electricity used in its production and thus Britain could not produce it competitively.

The factors of availability, cost and expediency, almost forced the decision to proceed with the Calder Hall project on the basis of natural uranium with graphite as the moderator. When the cooling medium came to be settled, here again expediency provided the same answer as the engineering and economic considerations and dictated carbon dioxide gas as the coolant. This almost makes it appear as though the designers had an easy task in making these decisions. Let me assure you that this was not so. The brilliant deductions leading to the final selections were outlined in a factual but quite excellent series of papers read before the British Nuclear Energy Conference in November, 1956.

What is important to Britain as a nation, to its electricity supply industry, and to British industry generally, is that those decisions taken by Hinton, Owen, Moore, and their colleagues, have produced in the Calder Hall nuclear power station a model which is the envy of the world. British industry trained and given experience by the United Kingdom Atomic Energy Authority, and in collaboration with them and the Central Electricity Authority and the South of Scotland Electricity Board, has produced advanced designs based upon and developed from Calder Hall, which have now commenced or are about to begin construction. These designs are "optimised" for electricity production and comply with the criteria outlined earlier. Fig. 1 shows a section through a model of the reactor and boiler of a typical advanced nuclear station.

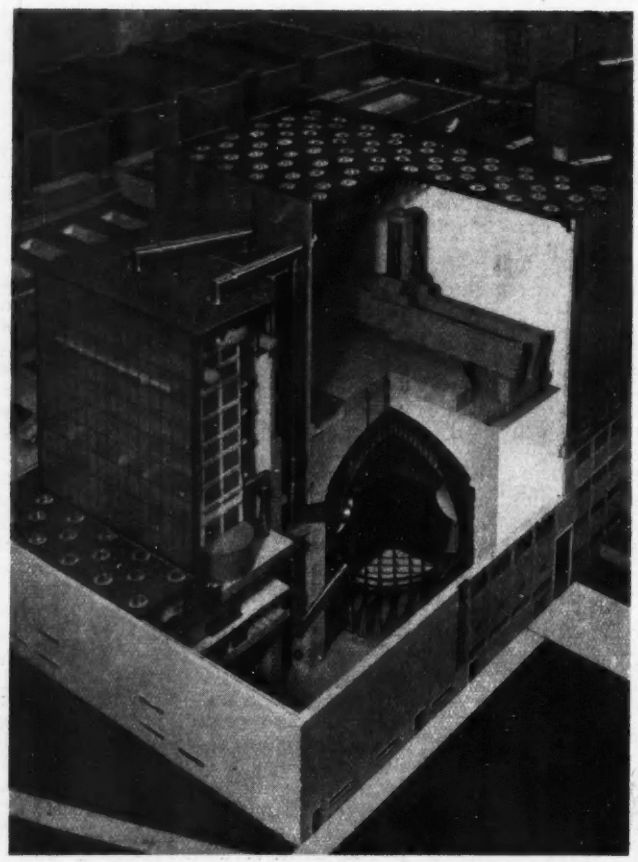
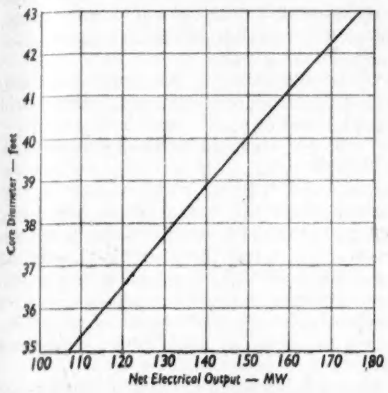


Fig. 1—Section through model reactor and boiler

It will be evident to all engineers that, just as the boiler size and the amount of fuel consumed per day in an orthodox coal-fired or oil-fired power station

* Chairman and Managing Director, C. A. Parsons and Co., Ltd., Newcastle upon Tyne.

determine the electrical output, so also does the reactor, its dimensions and fuel burn-up rate determine the output in a nuclear station. Hence the nuclear physicist and the turbo-generator designer must work hand in hand at every stage of design and development. But in between reactor and turbines are the equally interdependent circulators, ducts, boilers, and




Constant: maximum rating, reactor gas temperatures, maximum can temperature.

**Fig. 2—Core diameter and net electrical output**

auxiliaries. Of at least equal importance to all these plant items is the concrete shielding surrounding and encasing the reactors, which calls for great experience in design and construction to ensure safety for the operators against radiation effects. There are few, if any, engineering projects which demand such close co-operation between such a wide range of scientists and engineers, each a specialist in his own field.

## The Reactor

Nuclear calculations for a natural uranium, graphite-moderated, gas-cooled reactor are extremely complex and are greatly simplified and speeded up by the use of a special form of analogue computer for determining the power reactivity relationship of the core.

Nuclear physicists will state the minimum size of core and the amount of uranium to obtain criticality, and from this information and considerations of fuel rating the output expressed in megawatts from varying core dimensions may be determined. Fig. 2 shows a typical relationship. It will be appreciated that an increase in the core size above the critical pays a handsome dividend due to reduced leakage and the possibility of flattening by the introduction of an absorber, thereby increasing the mean rating of the fuel.

The maximum rating of the fuel in the centre channel of the core which very largely sets the seal on the reactor economy is determined by the maximum temperature permissible in the fuel rod and the can. These must be determined by the thermodynamicist and the metallurgist working in the closest collaboration.

These factors largely determine the mass flow of the gas and its inlet and outlet temperatures.

The heat exchanger or boiler designer must now decide how much steam, and at what pressures and temperatures it can be supplied to the turbines, whose designers then provide a figure for electrical output. The designers of the duct work and gas circulators then determine the pressure drop in reactor, ducts and boilers and, with a known mass flow, can design their portions of the plant.

But during this preliminary study the designers of the shield around and above the reactor have been calculating the amount of protective concrete and other materials required to limit radiation hazards, and their requirements certainly will affect the civil engineering and duct work layouts thus calling for design modifications. Many trial and error calculations are necessary before even semi-finality is obtained.

No mention has yet been made of the reactor pressure vessel designers, whose experience, views and potentialities are vital to final design decisions. Once the pressure vessel designer has been given a preliminary estimate of the reactor core dimensions, he can consider whether to use a cylindrical vessel as at Calder Hall, or a spherical vessel which so obviously is to be preferred if considered purely as a vessel to contain gas pressure. But he must consult the designers of the fuel element charging and discharging gear, because that mechanism requires certain space above the reactor core and also almost riddles the crown of the pressure vessel with holes or tubes to provide access to the fuel channels. The pressure vessel designer must also know the dimensions of, and how many, ducts carrying the gas have to be brought into the reactor shell. He must also consider how to transmit the very considerable weight of graphite and uranium through the vessel to the foundations without complicating and increasing locally the stresses resulting from the gas pressure. That harassed designer also has to consider the changes in temperature between inlet and outlet gases and the

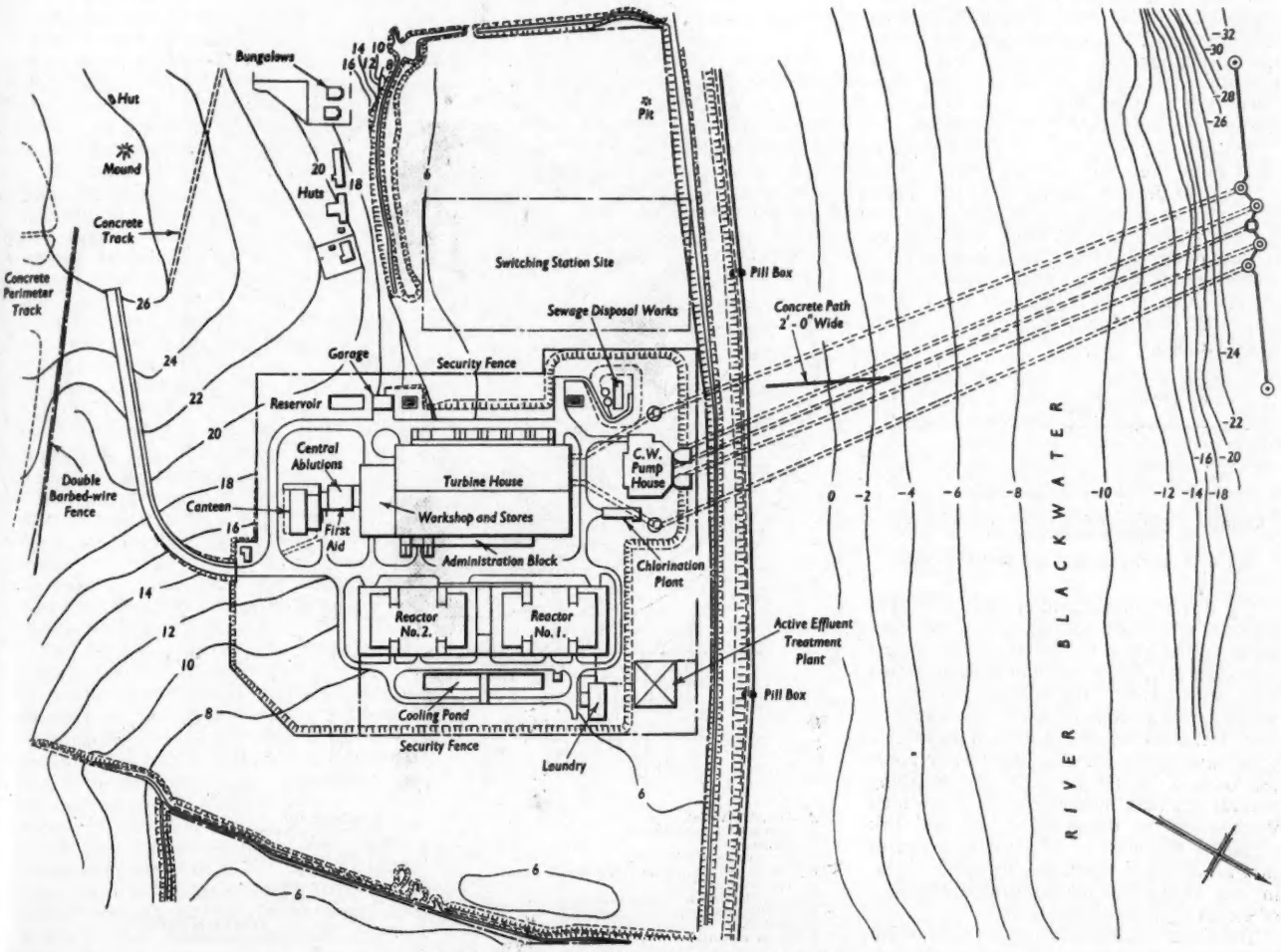


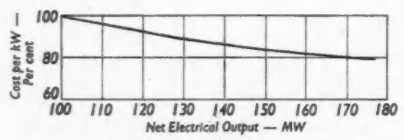

**Fig. 3—Layout of nuclear power station (Bradwell)**

stress pattern induced in consequence, and then face the crowning problem of the irradiation effects upon the shell materials available to him.

The higher the gas pressure the vessel designer can allow, then the greater the heat transfer from uranium through the can to the gas, the smaller the mass flow required for a given heat quantity removed and the lower the power needed for gas circulation, which thus increases the net electrical output from a given quantity of uranium. This auxiliary power used for gas circulation is particularly important in nuclear station design, since it may take some 10 per cent of the total potential useful power output of the reactor. It is the possibility of raising the net power output by reducing auxiliary power (and also raising the temperature of the cooling medium outlet with its improved steam cycle conditions and efficiency) that has turned the attentions of so many designers to the liquid-metal-cooled graphite-moderated reactor.

But for the generation of electricity for normal industrial use, it is essential that the changing of fuel elements should be done without affecting the electrical demand on the station. Changing fuel elements in a gas-cooled reactor is relatively difficult and calls for ingenious, costly and massive charge and discharge machines which now are available. The problems to be solved in changing fuel elements with liquid metal cooling whilst the reactor is on load are much greater and, when allied to the determining of faulty fuel elements, will call for exceptional ingenuity. This is one of the engineering problems awaiting an elegant solution and, when solved, will simplify reactor vessel design and lead to a marked improvement in fuel efficiency provided that the canning material allowing higher temperature does not nullify its advantages by absorbing too many neutrons or costing so much more than aluminium or magnesium oxide as to increase the cost of a unit of electricity produced.

The designer of industrial nuclear stations must never lose sight of his prime object, which is to produce electricity at the lowest cost possible consistent with safety and reliability. There are so many solutions to nuclear power problems that appear to offer advantages in one or other direction, but always either at the expense of safety or of generating cost so that they provide pitfalls to be avoided.




Constant : maximum rating, reactor gas temperatures, maximum can temperatures.

**Fig. 4—Capital cost and net electrical output**

Fig. 4 is a typical curve of capital cost per kilowatt of output plotted against net electrical output for a particular design of gas-cooled reactor, and shows how the capital cost falls with output. In practice the curve would be in a series of steps corresponding (amongst other factors) to steps in the reactor vessel wall thickness. But the reactor vessel for outputs of all possible designs using natural uranium necessitates at least final welding on the construction site and this limits the thickness of the pressure vessel to that which can safely be site welded, and this in turn limits upper gas temperatures because of metallurgical considerations.

The Calder Hall reactor vessels were of 2in thick special mild steel plate, but subsequent research and experimental weldings have shown that site welding of 3in plate is now possible and, with further experience, still thicker plates will be used in future with corresponding increases in pressure and efficiency. To change from the vertical right cylinder vessels as at Calder Hall to spherical vessels enabling higher gas pressures to be adopted necessitated finding solutions to many problems, not the least being the sealing of inlet and outlet gas paths from the walls to the core, doing this without adding appreciable temperature stresses to the already pressure stressed walls.

A fundamental philosophy of design in nuclear reactors should be never to put anything inside the vessel which has to move yet which cannot be removed and replaced once the reactor has been to full power and those parts have become strongly radioactive. Charge and discharge mechanisms and control rods should all be capable of withdrawal and replacement, if necessary. The full long-time effect of radiation is not as yet sufficiently known to face the possibility of failure inside the reactor of any moving parts which could not be removed.

## Central Electricity Authority Nuclear Power Station, Bradwell, Essex

The major particulars of the nuclear station at Bradwell, Essex, for the Central Electricity Authority are as follows :—

Guaranteed net electrical output: 300MW.

Reactor vessels : two reactors each contained in a sphere of 66ft in diameter in 3in thick special steel.

Heat exchangers : six heat exchangers or boilers per reactor with dimensions substantially similar to those at Calder Hall but with double the unit heat output.

Gas : carbon dioxide circulated at 10 atmospheres pressure.

Steam conditions : dual pressure cycle with steam at 730 lb per square inch gauge, 700 deg. Fah. and 180 lb per square inch gauge, 700 deg. Fah.

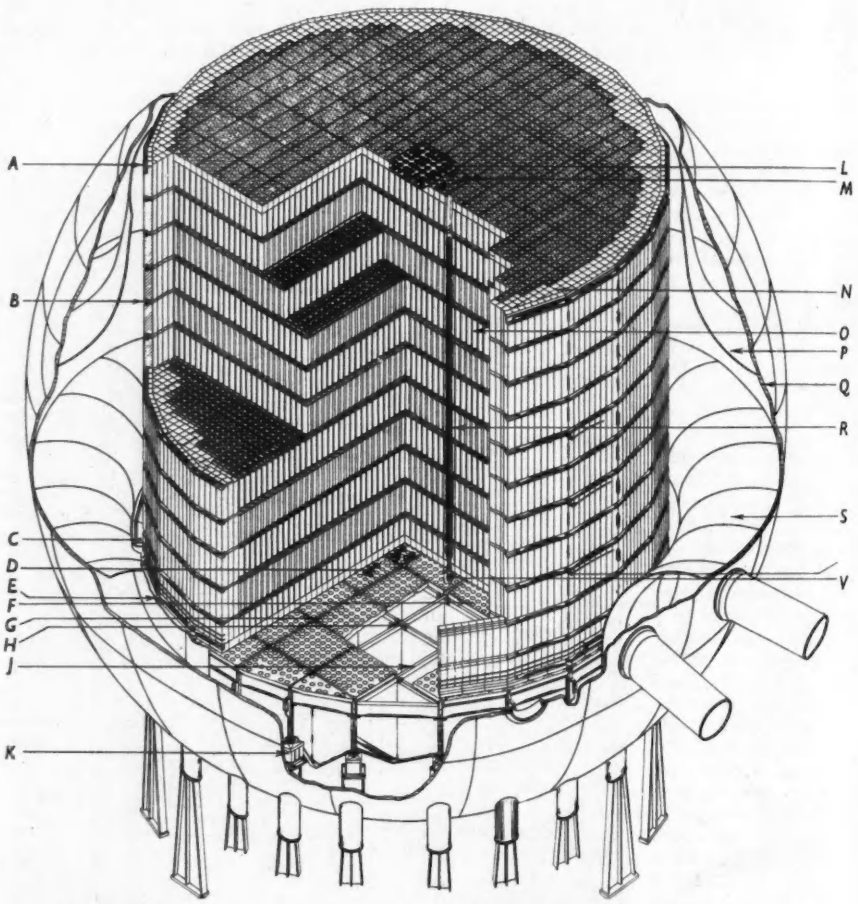
Cycle efficiency : net cycle efficiency, taking into account all station auxiliaries, will exceed 28 per cent.

Turbines : six main turbo-alternators, each of 52MW, and three auxiliary turbo-alternators which, together, supply power direct to the national Grid, to the station auxiliaries, and to the variable-speed reactor gas circulators. The total installed capacity of all machines is 390MW, which includes a margin for subsequent improvements in reactor performance. One of the auxiliary turbo-generators serves as a stand-by for the other two.

The main turbines have two cylinders with twin exhausts and are arranged across the station.

Fuel charging : reactor designed for continuous recharging of fuel while remaining at full output.

Goliath or gantry crane : the compact arrangement of reactor buildings has made possible the employment of a new tool for rapid erection of the station. This is a




*A*—Topside restraint.
*B*—Intermediate side restraint.
*C*—Gas seal.
*D*—Graphite support bearing.
*E*—Bottom side restraint and radial keys.
*F*—Support plates.
*G*—Levelling screws.
*H*—Levelling pads.
*J*—Diagrid.
*K*—Roller supports.
*L*—Charge pan.
*M*—Charge pan support.
*N*—Reflector bricks.
*O*—Moderator bricks.
*P*—Gas baffle.
*Q*—Pressure shell.
*R*—Fuel element.
*S*—Toroidal shield.
*T*—Wigner growth measuring device.
*V*—Fuel element support lantern.

**Fig. 5—Section through reactor core**

Goliath crane of height 140ft, span 167ft, lifting capacity 200 long tons.

Fig. 3 shows a layout of the nuclear station which is on the estuary of the River Blackwater, in Essex. The soil is mainly typical "London" clay and provides some difficult civil engineering problems.

Fig. 5 shows a section through the core of the reactors for the Bradwell station. The machining of the graphite blocks calls for a high degree of accuracy, to ensure the correct alignment of fuel-rod channels and to prevent neutron streaming at joints yet still allowing for some measure of Wigner growth. The geometry of core design demands great patience and critical analysis.

### Fuel Elements

A number of severe thermodynamic and mechanical problems are involved in the design of the fuel elements. The use of natural uranium as the fuel limits the canning material at present to magnesium or possibly aluminium. Magnesium is superior on two accounts—lower neutron capture and better compatibility with uranium—and has therefore been selected for Calder Hall and for the British stations now being built despite the well-known limitations in the physical properties of this metal. With magnesium the maximum surface temperature of the fuel can is limited to approximately 450 deg. Cent. (842 deg. Fah.) and the aim in design is therefore to obtain the optimum between the conflicting demands of high outlet gas temperature, high heat rating in the fuel, and an economic pumping power.

The choice of a suitable heat-transfer surface is further complicated by nuclear considerations. The amount of metal in the can, the channel diameter and the disposition of the fuel are restricted within certain limits by the nuclear design. The "optimisation" of all these parameters is a formidable problem which is always present as new surfaces and canning materials are developed and as further experience is obtained on core design with respect to fuel-rod geometry.

The mechanical problems are concerned with the support of the elements in the channel, and the forces imposed on the fuel and canning material by the method of support. Consideration must also be given to the handling of the element during charge/discharge operations at power, and the strength of the element must be sufficient to resist damage under these conditions.

Natural uranium changes its crystalline structure at about 650 deg. Cent. (1202 deg. Fah.). Though this in itself is not significant, the considerable change in volume accompanying it can lead, especially if repeated several times, to the complete loss of the mechanical strength of the fuel bar, and, what is more important, to the destruction of the container surrounding it, thus allowing fission products to escape. Consequently, for the time being, the temperature at which this $\alpha$–$\beta$ transition occurs dictates the temperature limit of the reactor.

For nuclear reasons, the shape of the uranium should be such that the ratio of surface to volume is small, but this is in direct contrast to the requirements for maximum heat removal. Practical reasons of support preclude the use of spherical fuel elements and, with one cylinder per channel, the fuel-rod optimisation requires a diameter slightly over 1in. Uranium is such a bad heat conductor that with the reactor on load there is a temperature drop of about 100 deg. Cent. from centre to periphery of the fuel rod. A further, though smaller, temperature drop occurs at the boundary between uranium surface and can surrounding it. The temperature drop in can wall and fins is small but that between can surface and cooling gas is appreciable and so is that between cooling gas and working fluid. All those temperature drops, which constitute thermodynamically irreversible losses, are a challenge to the applied physicist.

To reduce the temperature drop, we should work at high Reynolds numbers; apply large secondary areas, and create surface configurations which produce high heat transfer with relatively low pressure drops.

High Reynolds numbers necessitate, in order to keep pumping power within acceptable limits, high gas pressures or short channels. The gas pressure is limited by the pressure shell which is large and hot. Shortening of the channels leads to an increased diameter to height ratio of the core and thus reduced neutron economy, as well as uneconomic design of the pressure vessel.

Applying large secondary areas leads to increased neutron capture which, particularly with natural uranium, soon exceeds acceptable limits but also its thermodynamic effectiveness falls if the can fins become either too long or too close.

Hence it is to surface configuration that special attention must be given. The thermal conductivity in gases being low, the aim must be to scour the hot fuel element surface continuously by cooling gas, which is as nearly as possible at bulk gas temperature. This is best achieved if the gas which has been heated by contact with the fuel element is periodically transferred to, and replaced from, the main gas stream. It is important that this process be accomplished with the formation of few free vortices, which tend to increase the pressure drop without correspondingly increasing heat transfer. A considerable advance has been achieved by such a development.

The uranium in a power reactor will be at temperatures in the range 200 deg. to about 600 deg. Cent. (392 deg. to 1112 deg. Fah.), depending upon the position of the element in the core. At the higher temperatures, the uranium is relatively weak and there is also evidence that creep may be accelerated by irradiation in the low-temperature portion of the reactor. Therefore, the uranium must be arranged so that the forces imposed by its own weight are relatively small or, alternatively, supported continuously along its length to resist distortion.

Under irradiation, volume changes occur in the uranium, and the canning material must be sufficiently ductile to absorb these changes without splitting and thus exposing the uranium to the gas. The sealing of the ends of the can, the restraint applied by the extended surface and the metallurgical properties of the can are important.

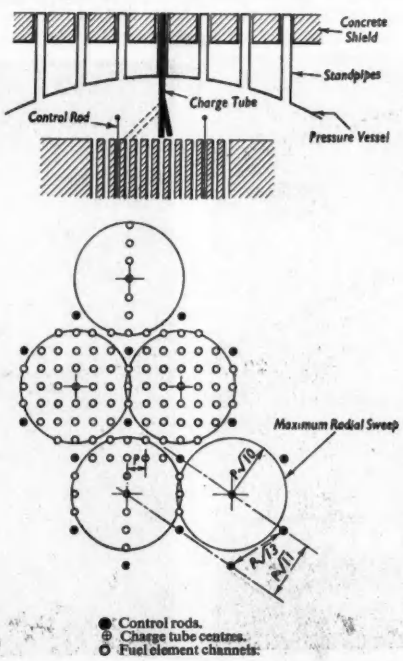



Fig. 6—Control rod and charging system

Fig. 7—Model of a portion of a pile cap

*Refuelling.*—For several reasons, including the containment of maximum size of core in a given pressure vessel, load of duct work, better natural circulation in the event of circulator failure, stress and differential movements in the core and pressure vessel, a core with vertical channels is preferable for power reactors. Refuelling has therefore to be carried out completely either from above or below or by passing new fuel in at the top and spent fuel out of the bottom. The last method has many attractions, but requires twice the equipment and cannot be justified economically. Systems for refuelling from below have been devised, but they involve the insertion of relatively complex mechanisms into the pressure vessel and operating rams into the core. Thus it is possible that their reliability may be less than the simple mechanisms which are gravity assisted when charging from above.

It is at least highly desirable that refuelling on load be carried out without interference to the control system. This implies the use of separate standpipes for refuelling and control rods. The necessity to achieve a minimum ratio between fuel channels and control rods in the core determines a minimum pitch of the control rod standpipes. The problem is to be able to insert charging standpipes between the control standpipes without weakening the pressure vessel, while maintaining adequate strength and the shielding properties of the reactor-roof biological shield, to achieve satisfactory coverage of fuel channels below the charging standpipes and avoid interference between the control rods and charging mechanism which has to be inserted into the vessel. A typical arrangement which meets these requirements is shown in Fig. 6. Fig. 7 shows the full-size model which was prepared to test accessibility and the ability to locate the essential reinforcing steel in the biological concrete shield.

*(To be continued)*

# The Building Frame and the Steel Shortage

By Professor A. L. L. BAKER, D.Sc.(Eng.), M.I.C.E., M.I. Struct.E.

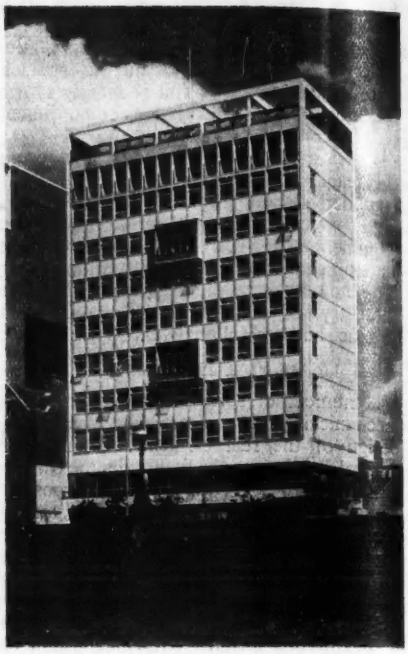
*This article contends that a very large tonnage of steel could be saved annually in Great Britain by the further use of reinforced concrete in place of structural steel building frames. Moreover, a saving in cost can be made and the time of construction reduced. On the Continent, in South Africa and the U.S.A. it is customary to construct nearly all building frames in reinforced concrete up to thirty stories in height. The architect's position in the matter is discussed. The design services provided by the reinforced concrete and the constructional steelwork industry are compared. The uncertain delivery of reinforcement has discouraged some architects from designing in reinforced concrete. An adequate stock of reinforcement kept well in excess of demand is necessary to ensure that demand is not restricted by fear of late delivery. An expansion of the rod rolling mills is required for this purpose, and an adequate supply of billets, if the import of rods is to cease and the reinforced concrete industry is to expand at an optimum rate in order to save steel.*

IN spite of a continued steel shortage and strained national economy, Great Britain still lags behind the rest of the world in adopting reinforced concrete as the normal material for constructing building frames. The term "building frame" denotes the skeleton of beams and columns which carry the floor and wall loads to the foundations. The frame is covered by an external cladding of brick or stone, so that the question of appearance, so often raised as an objection to concrete, does not arise.

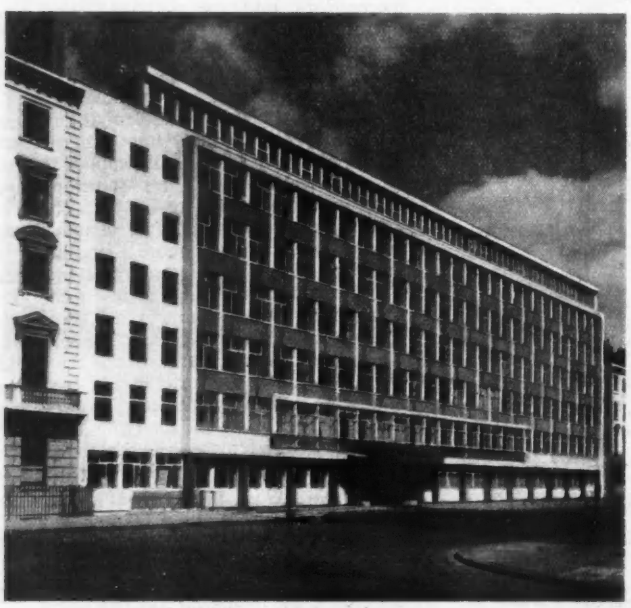
Reinforced concrete frames are cheaper than structural steelwork and require only about 40 per cent of the steel as reinforcement. For this reason, most other countries have almost completely abandoned the use of structural steel frameworks except for buildings over thirty stories in height. In the Scandinavian countries, no tall buildings of any importance have been constructed in structural steel since the middle 'thirties except one, in Copenhagen, which was financed by a British firm. In Germany, Holland, France and Italy, the use of structural steel frames for buildings for many years has been negligible. Reinforced concrete frames have been used up to fourteen stories in Rotterdam, eighteen stories in Oslo, seventeen stories in Stockholm. A building of twenty-six stories is now being built in Stockholm, and one of thirty stories in Italy. In Russia and Austria, the use of structural steelwork frames for buildings has been banned in order to save steel. In South Africa, and in particular in Johannesburg in the last twenty-five years, hundreds of tall buildings have been constructed with reinforced concrete frames, some up to twenty-five stories in height. In South America, thirty stories in height has been achieved, and in the U.S.A. it is considered economical to construct up to twenty-five to thirty stories in reinforced concrete, the reduction in cost of the frames being 25 to 40 per cent. In London, since 1950, many tall blocks of flats and some office buildings have been constructed with reinforced concrete frames. Some of these buildings are illustrated on these pages. But recently there appears to have been a reversion to the use of structural steelwork, particularly in City office buildings.

## Savings in Cost

The need for saving steel has been emphasised so much, and the tonnage used in building frames is so large, that it is of interest to seek the causes of Britain's unique position in this matter. From the published statistics of deliveries of steel to builders, constructional engineering firms and stockists in 1951, it may be deduced that about 500,000 tons were used in structural steel building frames. Since about 40 per cent of that quantity would be required as reinforcement in concrete frames, total substitution of structural steel by reinforced concrete would have saved 300,000 tons. Moreover, concrete frames are at least 15 per cent cheaper than steel frames, so that there would have been considerable saving in cost. Concrete frames are cheaper than steel frames, because only about 40 per cent of the steel is required as reinforcement, while about the same quantity of concrete and formwork is used. This is because it is necessary to provide at least 2in of concrete cover to structural steel for fire resistance. These comparisons of cost and quantities are substantiated by figures for recently constructed buildings in London. The fifth report of the Select Committee on Estimates refers to a saving of £150,000 on the second part of



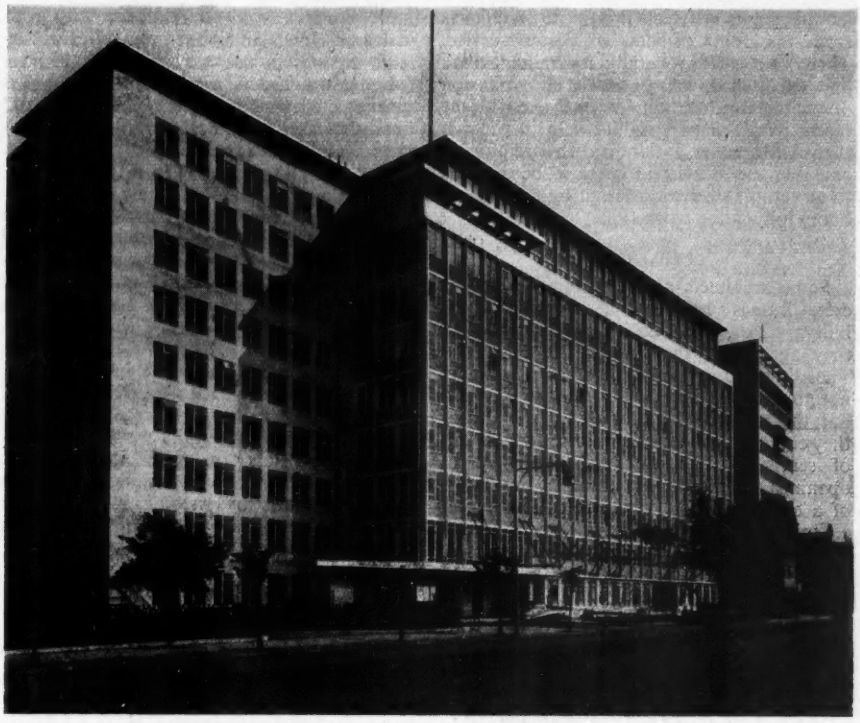
**Offices for the National Dock Labour Board, Albert Embankment, London, S.E.1**



**Headquarters of the J. Arthur Rank Organization in Belgrave Road, London**

**Sentinel House at the corner of Southampton Row and Theobald's Road, London**

Whitehall Gardens by the use of reinforced concrete, the estimated cost of the whole building being £3,532,000. Recent alternative lowest tenders for blocks of flats show a saving of £33,120 on a design including a steelwork frame quoted at £417,301. Another authentic figure for an eight-storey office block is a saving of £12,180 on £53,975 for a steelwork frame including hollow tile floors. Contractors experienced in both kinds of construction say that savings possible by the use of reinforced concrete are from 15 to 35 per cent of the cost of the frame. In 1952, "The Times Review of Industry" quoted as an indication of steel saving a block of flats requiring 880 tons of structural steel which used only 330 tons of steel bars when a concrete frame was substituted. A recent German report gives many examples of savings of 60 to 75 per cent of steel by the substitution of reinforced concrete for structural steel. Such savings are quite understandable since the compressive strength of concrete, according to the grade, is about one tenth to one fifth of the strength of mild steel. In a reinforced concrete frame only a light skeleton of steel rods is required to withstand the tensile stresses. The concrete is used both structurally and as a fire resisting covering to the steel.



Ten-storey office block at 20, Albert Embankment. The National Dock Labour Board's building is in the background

### Production of Reinforcing Rods

In spite of these well-known advantages of reinforced concrete, architects recently have invited tenders only for steel frames. A reason given by some is the uncertainty of delivery of steel rods, although structural steel has also been in short supply. In 1952, when there was a national deficiency of about 1,500,000 tons of steel, the possible saving in building frames was investigated and it was estimated that the reinforced concrete industry could expand its capacity by about 10 per cent per annum. Approximate Iron and Steel Board estimates indicate that the consumption of reinforcement increased from 261,000 tons in 1952 to 386,000 tons in 1955, including overseas contracts supplied from Great Britain. Of the 1952 deliveries, 63,000 tons were imported, and of the 1955 deliveries, 44,000 tons were imported. The estimate of 10 per cent was therefore too low. An expansion of 14 per cent per annum actually took place, with the assistance of imported reinforcement. If the same expansion rate continues the increase in the supply of rods would need to be at the rate of about 17 per cent per annum in order to avoid importing rods by 1958. The difficulties involved in the use of foreign steel naturally curtailed expansion. It is clear, therefore, that the rate of expansion of rod production has been too slow to enable the greatest possible advantage to be taken of the use of reinforced concrete for saving steel. Because of the shortage of rods many architects have felt more confident in the delivery of structural steelwork, particularly from the larger firms, although deliveries have also been slow. The production of reinforcing rods is a good indication of the amount of reinforced concrete work carried out. It is significant that in France, Germany and the U.S.A. by contrast, where there is also keen competition with structural steelwork, the following tonnages were delivered respectively in 1955 :—

| | Tons |
|---|---|
| France ... ... ... ... ... ... ... | 840,000 |
| Germany ... ... ... ... ... ... ... | 850,000 |
| U.S.A. ... ... ... ... ... ... ... | 1,903,000 |

For the future it is obviously most important that the delivery of reinforcing rods is sufficient, so that architects can specify the use of reinforced concrete frames, without fear of supply delays and difficulties. This is not an easy matter to arrange. Those sections of the steel industry accustomed to produce rolled steel joists will naturally tend to prefer an expansion in joist production. It would appear to be the responsibility of the Iron and Steel Board to guide investment, so that enough rod rolling mills are laid down, and to adjust prices so that there is sufficient incentive to divert enough billets to the mills to maintain an adequate supply of reinforcement.

### Speed of Completion

Most architects are now convinced that in the hands of a suitable contractor a reinforced-concrete-framed building can be completed as quickly, and often more quickly, than a steel-framed one. In South Africa, where labour is no more skilled than in London, it has been common practice to construct tall reinforced concrete buildings at the rate of a floor per week. Recently, flats at Wandsworth have been constructed at the rate of 4½ days per storey, and in Hamburg the frame of a twelve-storey block has been built in the remarkably short time of ten days. Other U.S.A. speed records are :

| Building | Town | Number of stories | Weeks for frame completion |
|---|---|---|---|
| Herrin Hotel ... ... ... | Amarillo, Texas | 14 | 14 |
| Winthrop Towers ... ... | Chicago ... | 12 | 9 |
| Whitehall apartment homes | Chicago .. | 21 | 21 |
| 300, W. Adam Street ... | Chicago ... | 12 | 9 |
| New Lawrence Hotel ... | Chicago ... | 12 | 12 |
| Detroit Towers ... ... | Detroit ... | 19 | 23 |

There is therefore ample evidence of the high rate of construction which can be achieved. Such work must, of course, be carried out by careful and experienced contractors, who are perhaps too few in number. There is a need for more contractors who are prepared to raise their standard of workmanship to that of the top-grade reinforced concrete specialist. Reinforcement bending and fixing, the process of mixing, placing, compacting and curing high-strength concrete, requires many leading skilled, well-trained hands, and a further expansion of the concrete industry must be accompanied by an increase in their number. There is, too, much scope for improvement in the preparation of drawings, so that they can be easily understood by the charge hands. Some firms still need to introduce better systems of detailing reinforcement and to mechanise the process of cutting and bending. This is very well done in South Africa, where African labour is employed for the work.

### Design

There is a great deal more work involved in designing reinforced concrete as compared with structural steel, and architects or consulting engineers may sacrifice considerable remuneration when they use it. It is important that scales of fees be arranged so that those who advise and design professionally are equally well paid, whichever material is used. Mr. F. J. Samuely, recently writing to the *Architects' Journal*, has pointed out that a consulting engineer gets about the same fee for a reinforced concrete frame as for a steelwork frame. The percentage is higher for concrete work, but the cost is less, so the fee received is about the same. In reinforced concrete design there is considerably more work involved. When the architect employs a structural engineering consultant, he is indirectly affected by this situation. Many architects take advantage of the excellent design service provided by constructional steelwork engineering firms, who quote on a tonnage basis for design, supply and erection of steel. The architect then, of course, is saved the cost of designing the frame. A few contractors supply a corresponding service for reinforced concrete design and construction, but the practice is not as well established as in the structural steel industry. In other countries, for instance in South Africa, it is the practice for a specialist firm to design, supply and fix reinforcement. There is great competition for contracts and the work of bending and fixing reinforcement is very efficiently carried out. In Great Britain a few firms design, cut, bend and supply reinforcement. There is need for improvement and expansion in this part of the industry if concrete frames are to become

as attractive as steel frames to architects from the point of view of design service. There is a need generally for more skilled and experienced designers. The expansion of technical education, as envisaged in the recent White Paper, should help to provide them. Moreover, it is hoped that reinforced concrete specialists will cease to be diverted to structural steelwork design by the present boom in building work.

### Flexibility

Some architects object to reinforced concrete frames because of lack of flexibility. For the initial general design they agree that there is greater flexibility. The dimensions of the frame members are not governed by standard sections and spans, but the advance erection of a steel frame, they claim, gives more time for settling details of services. The positions and sizes of openings are more likely to affect the design of a concrete frame which is continuous at all joints and with the floor slabs. This is not a serious objection, since the layouts of most city multi-storey buildings have much in common, and the structural arrangement of floors and frame must, to a great extent, follow a similar pattern. It should be possible to introduce a great deal of standardisation. Alterations which may be required after completion, due to change of use, are considered by some more difficult in concrete construction, because of the continuity of the beams and floor slabs. It is, however, usually not difficult to splice new reinforced concrete construction to existing work, which has been cut away in the correct manner. Certainly new steelwork can be joined by welding. It is just as easy with either system to alter partition layouts when adequately strong floor slabs have been provided. The objection to reinforced concrete on grounds of lack of flexibility need not be taken too seriously. It does not appear to worry the building owners and architects in other countries.

### Durability

The durability of concrete is sometimes questioned. There is, however, available now ample evidence of all kinds of concrete structures which are still quite sound after forty to fifty years of use, including many bridges and marine structures exposed to severe weathering. The tall buildings of Johannesburg are frequently subject to earth tremors and quite satisfactorily resist the shocks. The reinforced concrete framed buildings of Nagasaki showed astonishing strength in the face of atomic bomb blast. Tests to destruction recently carried out in Johannesburg on the Dental Hospital which was demolished showed that after many years reinforced concrete frames designed in accordance with existing building regulations have an ample reserve of strength.

### Alternative Methods of Construction

There are, of course, various economies which could be made in structural steelwork design and which should be mentioned. Continuous welded construction designed by plastic theory for smaller bending moments can reduce the weight of steel required, but not to the same extent as by the substitution of reinforced concrete. Some economies in steel can be made by using structurally the fire-resisting concrete in which the steel frames are encased. Design calculations then must be based on empirical formulæ established by tests. The concrete must be reliable structurally as well as for fire resistance. For this reason it is probable that invariably it will be cheaper to use a little more concrete and to reinforce with rods instead of joists and stanchions. In Switzerland there is in use a system of light steel framing which acts as reinforcement. It is first erected and used as scaffolding and finally encased, but normal reinforced concrete is almost always used for building work there and competes well with such alternatives.

In reinforced concrete construction there is great scope for the increased use of steel formwork and of precasting systems. It is an advantage to make high-grade concrete under factory conditions. Sections can then be lighter and the site work which requires skill and good weather is reduced to a minimum. In Russia, where building work has been planned on a sufficiently large scale, precast members for buildings have been standardised as large units weighing several tons. The units are made in automatic factories and erected by crane. They are generally joined by welding together steel plates projecting beyond the concrete in which they are embedded and anchored. Wherever building on a large scale is contemplated there is a great opportunity for the development of new and improved methods of prefabrication.

### Conclusion

The organisation and working of the steel and concrete industry, it has been shown, is complex. However, it is clear that, with a little adjustment, a large tonnage of steel could be saved in the building industry and used with great advantage elsewhere. It is most desirable that conditions of free competition should be established, so that for any large building neither concrete nor steel has an advantage due to supply conditions. For this purpose clearly the supply of rods must be kept ahead of the demand. It is important, too, that professional fees are arranged, so that architects and consulting engineers are equally well remunerated, whether they design in structural steel or reinforced concrete.

# Toll Roads in the U.S.A

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No. I

*A striking feature of the road developments in the United States of America in the past ten years has been the growth of toll roads. Some aspects of the planning, financing, operation and safety of the toll roads in the eastern States of America are described in this article which is based on information collected by the author during a visit to the United States in 1954–55. The modern toll road is a divided highway with restricted access, having no intersections, sharp curves or steep hills; there are no traffic lights, turning vehicles, pedestrians or cyclists. Like other major highways in America, toll roads are built to the highest engineering standards; the cost of their construction and operation is financed by tolls levied on those who use them. In this respect, toll roads provide one solution of the most pressing problem facing many countries today—the problem of financing new roads. The article gives a brief description of the planning, design, construction and cost of a typical toll road. Data on the usage of toll roads and the problems of traffic diversion and generation are discussed. Information is given on the types of accident occurring on toll roads and on the accident studies which have led to the adoption of various safety measures; in some cases these have greatly reduced the accident rate in spite of a considerable growth in traffic. The number of accidents and the number of personal injuries sustained per million vehicle miles are generally much lower on toll roads than on other main roads. The author's impressions of driving on toll roads under different weather and traffic conditions are also given.*

ONE of the great problems facing many countries to-day is how to finance the road developments which are necessary to cater for the rapid increase in the number of motor vehicles in use. Even in the United States, where an enormous amount of money has been spent in providing new roads, the growth in the vehicle population has outstripped the growth of the road system and there is a continual demand for more and better roads. The American approach to the road problem differs markedly from the British approach. In the United States, the economic benefits resulting from good roads are widely recognised; nobody disputes the need for good roads or the need to spend large sums of money in building them. There are differences of opinion on how the money should be raised, but so great is the demand for road transport that people would rather pay extra to have roads to use than do without.

The building of roads financed by tolls levied on those who use them is one solution of the problem of financing new road construction, and its success in the United States is exemplified by the growth in the last few years of the system of toll roads in the eastern and central States. The total mileage of new toll roads has, in fact, greatly exceeded that of other high quality roads in these States. In 1953, out of 1920 million dollars (£710 million) spent on highway construction and improvements in the whole of the United States, 480 million dollars (£155 million)—or 25 per cent—were spent on toll roads.[1]

This article contains information, collected by the author during a visit to the United States in 1954-55, on some aspects of the planning, financing, operation and safety of toll roads. Its chief interest lies not so much in the fact that the roads are toll roads, but that they are representative of modern road construction of the highest quality in which every attempt is made to build a durable, economical and safe highway. Many valuable lessons can be learnt from a study of these roads by those who are concerned with the planning and construction of motor roads and similar high quality roads. Although this article is confined to a study of toll roads, it should not be inferred that the construction of high quality toll-free roads has ceased or that toll roads possess peculiar advantages over toll-free roads. On the contrary, many miles of toll-free expressways, parkways and similar limited-access roads have been built, largely in, or linking, urban areas. Much of what

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is said in this article applies also to these toll-free roads, but more reliable information, particularly as regards accidents, is available for the toll roads.

### Description of Toll Roads

The function of toll roads, like that of other major highways, is to provide easy and rapid travel between important centres of production and population and to cater for the large-scale tourist traffic. Toll roads are essentially rural roads and although parts of them are built through urban areas, they do not pass through large cities ; easy access to the cities is usually provided by a system of feeder roads. The modern toll road, however, bears little resemblance to the usual type of rural road. It is generally a four-lane divided highway with limited access ; there are no intersections, traffic lights or turning vehicles and no pedestrians or cyclists. Generally, the sight distances exceed 1000ft and there are no sharp curves or gradients exceeding 3 per cent. Attractive restaurants and fully equipped service stations are provided at well spaced intervals ; apart from these, there are no buildings alongside the toll roads and there is a complete absence of distracting advertisements. High average speeds can easily be maintained and, apart from the saving of time, drivers find the toll roads convenient in avoiding the ever-increasing congestion in built-up areas and the difficulty of finding their way through unfamiliar towns.

Table I gives a list of the toll roads in use or under construction in January, 1955.

Table I—*American Toll Roads (January, 1955)*

| *Summary* : | Length in miles | Cost in millions of dollars |
|---|---|---|
| Toll roads in service | 1465 | 1838 |
| Toll roads under construction | 920 | 1737 |
| Proposed toll roads | 3719 | 4530 |
| | 6104 | 8105 |
| *Toll roads in use* : | | |
| Buccaneer Trail, Florida | 17 | 5 |
| Denver Boulder Turnpike | 17 | 6 |
| Garden State Parkway | 164 | 353 |
| Long Island Toll Parkways | 31 | 34 |
| Maine Turnpike | 47 | 21 |
| Merritt and Wilbur Cross Parkways, Conn. | 67 | 38 |
| New Hampshire Turnpike | 15 | 7 |
| New Jersey Turnpike | 118 | 285 |
| New York State Thruway | 427 | 587 |
| Pennsylvania Turn ike | 360 | 306 |
| Turner Turnpike, Oklahoma | 88 | 38 |
| Westchester Parkways, N.Y. | 26 | 25 |
| West Virginia Turnpike | 88 | 133 |
| | 1465 | 1838 |
| *Toll roads under construction* : | Length in miles | Estimated cost in millions of dollars |
| Connecticut, Greenwich-Killingly Expressway | 129 | 400 |
| Indiana East-West Toll Road | 156 | 280 |
| Kentucky, Louisville-Ellizabeth Town | 40 | 40 |
| Maine Turnpike Extension, Portland-Augusta | 66 | 55 |
| Massachusetts East-West Toll Road | 123 | 240 |
| New Hampshire, Massachusetts Border to Concord | 40 | 22 |
| New Jersey Turnpike, Hudson County Extension | 8 | 114 |
| Link to Pennsylvania Turnpike | 6 | 27 |
| Ohio Turnpike No. 1—Pennsylvania Border to Indiana Border | 241 | 326 |
| Pennsylvania Turnpike Extensions | | |
| Link to New Jersey Turnpike | 1 | 233 |
| Philadelphia to Scranton | 110 | |
| | 920 | 1737 |

An additional 3719 miles of toll road have been authorised or are under study by public agencies in twenty States at an estimated cost of 4530 million dollars.

The most heavily trafficked toll roads include the Pennsylvania and New Jersey Turnpikes, New York Thruway, Garden State Parkway, and Maine Turnpike. From the engineering aspect, perhaps the most spectacular is the West Virginia Turnpike. Some particulars of the New Jersey Turnpike are given below as a typical example of a modern toll road.

The New Jersey Turnpike serves the heavily industrialised areas of Philadelphia and New York and caters for the enormous tourist traffic to the New Jersey beaches and to the New England vacation regions. New Jersey has had the problem of providing for what is possibly the largest and most rapidly growing volume of traffic in the world ; it is estimated that about 15,000,000 people live or work within a few miles of the Turnpike. This is now 118 miles long, but is already being extended to the north and to the west ; it runs from the George Washington Bridge, which crosses the Hudson River at New York, to the Delaware Memorial Bridge crossing the Delaware River near Wilmington. Over this distance it has reduced travel time by about two hours. Although built through flat country, the Turnpike cost about 285 million dollars to build, i.e. over 2,000,000 dollars per mile. Part of this large sum was used to finance the building of 263 bridges, sixty-nine to carry the Turnpike over rivers or streams, and 194 to carry intersecting roads or railways over the Turnpike.

Access to the Turnpike is by means of interchanges which are strategically located to connect with major highways and local centres of population or industry ; they are designed to bring vehicles as safely as possible on to and off the Turnpike. Sometimes their design is of necessity very complex, as when they link with other major roads near large towns, but little difficulty is experienced in negotiating these interchanges if they are well sign-posted. At each of the seventeen interchanges there are toll booths ; on entering, a driver is given a punched ticket and on leaving at some other interchange the driver surrenders the ticket and pays the appropriate toll. On most toll roads a charge of about 1 cent per mile is made for passenger cars ; on the New Jersey Turnpike, however, the toll rate is about 1 cent per mile for the southern 100 miles and rises to about 4 cents per mile for the final 18 miles into New York. The total toll for the whole 118 miles is 1·75 dollars (12s.) for a passenger car, 3·50 dollars for a two-axle dual-tyre truck, 4 dollars for a three-axle, single-unit truck, 4·50 dollars for a three-axle, semi-trailer combination, and 5 dollars for a four or more axle semi-trailer combination.

Over most of its length, the New Jersey Turnpike is a dual carriageway with 12ft lanes, but on the most heavily trafficked section of about 20 miles, near New York, there are three lanes in each direction. Plans are in hand for widening this stretch to four or six lanes in each direction. The median strip is generally 25ft wide and there are two hard shoulders, 5ft wide adjacent to the median strip, and 10ft wide on the other side. Drivers are forbidden to pull off the road on to the shoulders except to make essential repairs. There is a central white line in "reflectorised" paint on each carriageway and distance markers with a "reflectorised" disc are uniformly spaced along the road at about 200-yard intervals. Road signs are in large, clear "reflectorised" letters and the message is terse ; they are easy to read by day or night when travelling at 60 m.p.h. and give the driver ample warning of exits. There are ten combined restaurant and service stations, each with adequate parking facilities and safe exit and access lanes of the interchange type. Radio-controlled service trucks patrol the road and render speedy aid in the event of breakdowns. The maximum speed limit is 60 m.p.h. for all vehicles and vigorous attempts are made to enforce the speed limit by constant police patrols and radar speedmeters. The police cars are equipped with radio and are in continuous contact with the Turnpike Authority headquarters at New Brunswick.

### Planning of Toll Roads

The procedure adopted in planning the Pennsylvania Turnpike may be considered typical. Planning began in the late thirties, when the transport of Pennsylvania's industrial and agricultural products to the eastern cities and seaboard created a demand for a road which would overcome the delays experienced on the congested and hilly roads then in use. A traffic and origin-and-destination survey indicated approximately the route to be followed ; land surveys were then made and several possible alternatives were closely examined for engineering difficulties to be overcome and with costs of construction in mind. A route was finally agreed and a right-of-way 200ft wide, with the extra land needed for interchanges and service areas, was acquired by the Turnpike Commission. The land requirement averaged about 30 acres per mile of road. Construction began on October 27, 1938, and the first 160 miles were opened to public travel on October 1, 1940. Subsequently, extensions of 100 miles and 67 miles were constructed and by the end of 1951, 327 miles were in use. Some 360 miles are now in use and further extensions planned may increase the total length to about 750 miles. The same planning procedure has been followed elsewhere except that a 200ft right-of-way has not always been acquired. It is considered now, however, that a right-of-way of less than 200ft does not permit a wide enough median strip or provide for possible future widening.

In surveying sites for proposed roads, aerial photographs have been extensively used. Map sheets for a 140-mile extension of the Pennsylvania Turnpike were prepared in 145 days by a photogrammetric firm at an estimated cost of one-fifth of that for conventional survey methods. Recently, 475 miles of the proposed Illinois Turnpike were mapped in seventy-five days. Some land survey work is, of course, necessary to supplement the aerial work, and here new methods are being applied. Seismic surveys to locate rock and other strata below the surface have been used in preparing plans for the proposed toll road in Connecticut.

Much of the planning of toll roads is now done by firms of consulting engineers who specialise in this type of work. Some of these firms employ permanent staffs of about 100, but take on temporary staff of up to about 150 when working on a large project. Most of the preliminary planning work is concerned with traffic and origin-and-destination surveys ; this is followed by the work of costing (land acquisition, construction costs) and of assessing the likely revenues from tolls. In the latter connection it is desirable to know the rate at which traffic will increase and how much traffic will be attracted from other roads ; reliable estimates are difficult to obtain and most of the assessments made so far have been underestimates.

### Financing of Toll Roads

The construction of toll roads is financed by the issue of bonds. These bonds bear preferential rates of interest, in that investors do not have to pay Federal or State tax on earnings derived from the bonds. Thus, the toll roads are, in effect, subsidised by the U.S. Government, and in fact receive preferential treatment because similar tax concessions are not granted to the holders of railway or public utility bonds. The tolls collected from users of the roads go towards

redeeming the bond debt and paying for the whole cost of operation, maintenance, improvements or extensions. Fines collected for speeding or other violations go to the State to help defray the costs of the courts ; taxes on fuel sold on the turnpike (amounting on the New Jersey Turnpike to over 1,000,000 dollars a year) go to the State and Federal Governments for the purpose of building or maintaining toll-free roads.

As an example of the procedure for financing a new toll road, reference may be made to that adopted by the State of Pennsylvania in constructing the Pennsylvania Turnpike in 1937. The State Legislature set up a Turnpike Commission consisting of five members, four appointed by the State Governor with the approval of the Senate, plus the Secretary of Highways as an *ex-officio* member. This Commission was given power to issue revenue refunding bonds payable solely from tolls, and to construct, operate and maintain the turnpike, with the proviso that the location of the turnpike was subject to the approval of the Department of Highways. The Commission was further granted powers to acquire property by compulsory purchase ; this power is referred to as the power of condemnation or " eminent domain " ; it was a potent factor in enabling construction to proceed, without the delays arising in settling compensation for land or property. The Commission was not required to pay any State tax on land acquired. It was also laid down that, when all the bonds and the interest on them had been paid, the Turnpike was to become a part of the system of State Highways and be controlled by the Department of Highways, the Commission was to be dissolved and the tolls abolished. Full details on all these matters are given in the Acts of the General Assembly of the State of Pennsylvania.[2]

Other States have followed Pennsylvania's example and similar legislation has been passed and Turnpike Commissions or Authorities have been set up. At the present time Wall Street Market quotations are given regularly for tax-exempt toll road bonds issued in respect of about twenty toll road projects, and it is obvious from the prices quoted that these bonds are attractive investments.

### Some Economic Aspects of Toll Roads

Much has been written in the United States about the economics of toll roads and other major highways. The financial benefits, in terms of the savings in fuel and operating costs of commercial vehicles, and in terms of time saved by the occupants of passenger cars, are frequently quoted,[3, 4] and are the subject of a great deal of study. Some particulars of the receipts and expenditure on toll roads in 1953 are given in Table II. Excluding capital outlay on new construction and improvements, about 20 per cent of the total expenditure was on maintenance and operation, about 30 per cent on interest repayments, and about 50 per cent on the retirement of obligations.

### Construction and Design of Toll Roads

Much information on the design and construction of toll roads is given in two articles[6,7] describing the New Jersey and the Pennsylvania Turnpikes. The largest types of specialised mechanical plant are used in building toll roads. Increasing use is now being made of large mobile plants for rock crushing and grading and for the manufacture of concrete or bituminous materials on the site. During the construction of the New Jersey Turnpike, for example, four Madsen batching plants produced as much as 6000 tons of hot-mix asphalt in a single day. The fifty major constructors used 45,000,000 dollars' worth of plant and equipment. As a result the New Jersey Turnpike was completed in less than two years, despite difficulties caused by the war in Korea. The power of eminent domain previously mentioned facilitated rapid construction ; compensation for some of the land acquired has not yet been settled.

Although some of the toll roads pass through uninteresting country, those passing through more interesting country take full advantage of the terrain ; in every case much thought has been given to the problem of making the road fit the landscape and it is common, for example, to see bridges painted green or brown to blend with the adjacent vegetation. Great care is taken to obtain a superior finish to the road surfaces. Profilometers are usually used for checking the contractors' work. The good surface finish, in conjunction with the " soft " suspension of most American cars, provides an exceptionally smooth and comfortable ride. Some toll roads have a surface of plain concrete with uniformly spaced joints. Although these joints are well made, the impacts which occur when the wheels of cars pass over them are transmitted as sound impulses to the car interior and these can be irritating on a long journey.

The construction of toll roads differs in different States depending on the nature of the soil and on the aggregates available locally. A detailed description of the flexible pavement on the New Jersey Turnpike and of the rigid pavement construction on the Pennsylvania Turnpike has been given by Clare.[8] The New Jersey Turnpike, fof example, has a total depth of construction or about 40in, of which the bottom 18in to 24in consists of mechanically stabilised soil. On this was laid about 6in of well-graded broken stone or crushed gravel and a course of about 5in of waterbound macadam and 3in of penetration macadam ; the top layer is 4½in of rolled asphalt. This road was designed for axle loads of 36,000 lb and it was intended that the surface should not require major repair for at least twenty years.

On most toll roads, the shoulders are hard, i.e. they will support vehicles without deformation, and they are easily differentiated from the roadway itself by a difference in colour or surface texture, in marked contrast to the shoulders on many rural roads. On some toll roads, there is a white " reflectorised " line running along the inner shoulder edge or there is a narrow " singing strip " consisting of a corrugated concrete surface which makes a clearly audible note inside the vehicle and warns the driver that he is about to run on to the shoulder.

The sign-posting of toll roads is usually excellent, in marked contrast to that on many other roads.[9] Good signs are necessary because they have to be read from fast-moving vehicles ; moreover, if a driver overshoots a sign marking his destination exit, he may have to travel many miles before he can turn. Twelve inch lower-case letters are usually used for place names, but interchange numbers are usually in 30in letters. Many signs have a reflecting background, often in dark green or blue. The signs generally give the driver advance information about exits and place names, repair and refreshment facilities and merging traffic (at interchange areas) ; periodically they draw his attention to the maximum speed limit, and to the prohibition against stopping except for repairs, and against making U-turns. Other signs, usually in neon lighting, give warning of bad weather on the road ahead (e.g. on the New Jersey Turnpike, advance warning of fog is displayed on the sides of bridges which cross the road ; in bad weather, signboards are clipped on to the existing maximum speed signs to notify drivers of a reduction in the maximum speed limit). On the New Hampshire Turnpike, the driver is warned that he is exceeding the speed limit by a large illuminated sign (operated automatically from a radar speedmeter installation) which reads " You are exceeding the speed limit."

Road surface markings consist mainly of the usual types of lane marking. At the approaches to toll booths, some roads have " deceleration lanes " consisting of yellow transverse lines which are intended to provide drivers with a means of gauging their speed so that they can come safely to a stop at the booths.

At places where there is a ditch or embankment or other possible hazard at the side of the road, guard rails are erected on most toll roads. These are of various types, but wooden posts with three steel cables strung between them are common on the newer roads. Others consist of curved or corrugated sheet-metal panels supported by wooden or concrete posts or shallow shaped concrete barrier rails.

The design of toll booths is now practically standardised.[10, 11] Considerable thought has been given to ensuring the easy and safe entry and exit of vehicles, the adequate lighting and heating of the booths and facilities for collecting tolls, giving change and banking the considerable sums of money collected. Usually the separate booths are connected by an underground passage. A large staff is sometimes required to operate the booths on a busy toll road ; there is a 24-hour service and at peak-traffic periods, there may be six to ten booths in operation at each interchange. Generally one man supervises the operation of the whole booth

Table II—*Receipts and Expenditure on Some Toll Roads in* 1953* (*in Millions of Dollars Approx.*)

| Name of toll road | Total receipts (1) | Capital outlay (2) | Maintenance and operation (3) | Interest on obligations (4) | Retirement of obligations (5) | Total expenditure (6) | Total expenditure less capital outlay (6)—(2) (7) | Total receipts less total expenditure (1)—(7) (8) |
|---|---|---|---|---|---|---|---|---|
| Maine Turnpike | 74·9 | 0·4 | 0·3 | 3·5 | 20·3 | 25·2 | 24·9 | 50 |
| New Jersey Turnpike | 169 | 14·8 | 2·9 | 11·8 | 30·0 | 62·7 | 47·9 | 121 |
| Garden State Parkway, N.J. | 149 | 67·8 | — | 2·6 | — | 72·3 | 4·5 | 144 |
| New York Thruway | 254 | 157 | 0·3 | 2·3 | 10·0 | 196 | 39·0 | 215 |
| Pennsylvania Turnpike | 24·3 | 21·8 | 4·1 | 7·8 | 7·4 | 41·9 | 20·0 | 4·2 |
| Delaware River Memorial Bridge | 6·5 | 0·5 | 0·4 | 1·8 | 0·7 | 3·6 | 3·0 | 3·4 |
| Holland and Lincoln Tunnels, George Washington and Staten Island Bridges, N.Y. | 56·6 | 11·5 | 12·3 | 1·8 | 14·5 | 47·0 | 35·5 | 21·0 |
| Totals :† | | | | | | | | |
| Toll roads | 686 | 365 | 10·0 | 44·4 | 68·6 | 523 | 158 | 528 |
| Toll bridges and tunnels | 301 | 68·7 | 22·5 | 17·2 | 35·8 | 156 | 87·7 | 213 |
| Toll ferries | 12·3 | 0·9 | 9·9 | 0·3 | 1·0 | 12·6 | 11·7 | 0·6 |
| Grand total | 1000 | 434 | — | — | — | 692 | 258 | 742 |

* Extracted from Highway Statistics, 1953, U.S. Department of Commerce, Bureau of Public Roads.[5]
† Including toll roads not quoted above.

station ; he decides the number of booths which shall be assigned to incoming and outgoing vehicles and handles any eventualities which may arise, such as a delay at a particular booth. Recently, some thought has been given to mechanical means of collecting tolls and one such system is being tried out on the Garden State Parkway.

Except for the entrance and exit toll booths at each end of the road, all toll booths are situated off the road and are usually reached after traversing a clover leaf or other similar interchange road which connects with the toll road by acceleration or deceleration lanes, usually about 1200ft long. These interchanges can only be negotiated at low speeds and little difficulty is experienced in stopping at the booths. Most of the accidents which do occur at toll booths usually take place at the entrance and exit booths and then mostly on the exit side ; this is said to be due to the inability of drivers to judge the lower speeds after travelling for some time at a high speed. Shallow concrete deflection and guard rails are placed round the booths to protect them and the operators and to minimise damage to vehicles in the event of a driver being unable to stop in time.

On some toll roads, weed control is necessary to prevent soil erosion, or to eliminate undesirable weeds which interfere with drainage, obtrude over the road verges and sometimes create fire hazards. Some turnpike authorities have devoted much attention to these problems. The use of selective chemical weedkillers and fertilisers has been studied[12] and machines have been developed for treating long stretches of road. On some roads where erosion of embankments presents a problem, new strains of plants have been developed for slope control ; these are not only effective for this purpose but provide a colourful spectacle for most of the year.[13]

### Usage of Toll Roads

As soon as the Pennsylvania Turnpike was opened it became evident that the number of vehicles using the road was much greater than had been estimated. Not only was there an unexpectedly greater diversion of traffic from other roads, but it appeared that greater vehicle usage was encouraged by the existence of a good fast road. The potential value of the road for the rapid transit of goods and raw materials encouraged the growth of industries near the road and this further increased traffic. The growth of traffic on this Turnpike is shown in Table III.

Table III—*Growth of Traffic on Pennsylvania Turnpike*

| Year | Vehicles using Turnpike, in millions | Miles driven, in hundreds of millions | Average trip length in miles |
|---|---|---|---|
| 1940 | 0·56 | 0·46 | 82 |
| 1941 | 2·63 | 2·42 | 92* |
| 1942 | 1·52 | 1·28 | 84 |
| 1943 | 1·00 | 0·87 | 87 |
| 1944 | 1·14 | 0·97 | 85 |
| 1945 | 1·60 | 1·43 | 89 |
| 1946 | 2·60 | 2·45 | 94 |
| 1947 | 3·10 | 2·92 | 94 |
| 1948 | 3·56 | 3·43 | 96 |
| 1949 | 4·05 | 3·91 | 97 |
| 1950 | 4·77 | 4·76 | 100 |
| 1951 | 7·78 | 7·74 | 100 |
| 1952 | 11·37 | 11·42 | 100 |
| 1953 | — | 12·06 | — |

By 1952 seven times more vehicles were using the Pennsylvania Turnpike than were using it in 1945. The average trip per vehicle, however, remained approximately constant at about 100 miles. In 1952 the average daily traffic volume was about 30,000 vehicles, of which one-third were commercial vehicles. The average toll revenue per mile driven was 1·73 cents.

In 1953 more than 22,000,000 vehicles used the New Jersey Turnpike and the aggregate mileage was nearly 870 million miles, corresponding to an average trip per vehicle of about 40 miles. The average daily traffic volume was about 60,000 vehicles, of which less than 10 per cent were commercial vehicles, and the average toll revenue per mile driven was 2·2 cents.

A study of traffic on toll and other roads by the Bureau of Public Roads[14] has yielded information on the diversion of traffic to toll roads and on the increase in traffic throughout the area containing the toll roads (this is called traffic generation). Diversion and generation are important factors in planning toll roads ; partly as a result of lack of knowledge on these subjects, costly widening of existing toll roads has had to be undertaken.

The first studies on traffic generation were made on the Maine Turnpike ; there is only one other major road (U.S.1) near the Turnpike and therefore little likelihood of traffic diversion from other main rural roads. Since its opening at the end of December, 1947, traffic on the Turnpike and on U.S.1 has increased by more than 80 per cent, the Turnpike carrying about half the total traffic. On other main rural roads in the State, the increase in traffic has been about 40 per cent. At first, traffic generation on this Turnpike was rapid, but it is now approaching a constant rate ; traffic is increasing on the Turnpike at a steady rate of about 40 per cent greater than that on other main rural roads in the State. On the Pennsylvania and New Jersey Turnpikes, in addition to the traffic generated by the Turnpike, there has been a considerable diversion of traffic from other roads.

Because of the difficulty of distinguishing between traffic generation and diversion, some workers are using the term "induced traffic." Whatever its origin, induced traffic is a common feature on all roads and bridges which offer a more rapid or convenient mode of travel. The amount of induced traffic, however, varies considerably and forecasts of its magnitude are difficult to make. On the New Jersey Turnpike, for example, the induced traffic has continued to grow at such a rapid rate, especially at the approaches to New York, that widening of the existing road will be necessary. Built in 1951, the Chesapeake Bay Toll Bridge had been less than four years in operation, when traffic using it exceeded the estimated traffic for 1970[15] ; this was in spite of the fact that the toll charge for a single crossing of the bridge by a passenger car and driver is 1·40 dollars (10s.), with a charge of 25 cents for each additional passenger. It is obvious that induced traffic presents a difficult problem to road engineers in designing new roads, and considerable attention is now being given in the United States to a study of this problem.

The Bureau of Public Roads has carried out origin-and-destination studies by means of interviews at stations on roads adjacent to the Maine Turnpike, both before and after its opening, as well as at all the toll interchanges.[16] Similar studies are now in progress on the Pennsylvania Turnpike. These studies indicate that many factors influence the use made of these Turnpikes. On the Maine Turnpike, for example, there is a marked seasonal variation in the proportion of cars and commercial vehicles which use the Turnpike compared with the toll-free road U.S.1. Drivers on long trips tend to use the Turnpike rather than the alternative route. On the Pennsylvania Turnpike, the proportion of cars and commercial vehicles using the eastern portion of the Turnpike, compared with that on other roads, is much greater than the proportion using the western portion, probably because the alternative routes in the eastern section have steep gradients and sharp curves.


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(*To be continued*)

## Economics of Speed

Addressing the Institute of Transport last Monday, Marshal of the Royal Air Force Lord Douglas of Kirtleside observed that it was claimed for turbo-prop aircraft that they were the least costly aircraft, whereas by flying 100 or 150 m.p.h. faster jet airliners were able to show equal costs on formula ; this, he thought, might well be the subject of an independent study. His experience showed that actual aircraft costs were higher than "formula" aircraft costs, and it was necessary to adjust for this effect. He examined the airline turbo-jet and turbo-prop experience to date by a study of B.O.A.C. "Comet" and B.E.A. "Viscount" operations. The turbo-prop was initially 32 per cent higher than formula, but established itself 21 per cent above formula. The "Comet" when in use exceeded formula costs by 61 per cent (engineering costs were 2·6 times, and fuel and oil costs 1·3 times, estimates), but would probably have achieved costs 35 per cent above formula. On this basis, Lord Douglas expected that future jet aircraft would be 8 per cent further above formula costs than turbo-prop machines. Taking the ratios of actual to formula aircraft costs as 1·0 for the turbo-prop and 1·08 for the jet, and assuming indirect costs at 60 per cent formula aircraft costs, total costs for a 575 m.p.h. jet would then appear to be 7 to 10 per cent higher, at the design range, than for a 460 m.p.h. turbo-prop ; the difference would increase at longer ranges. For a 375 m.p.h. turbo-prop, the advantage would be 11 to 14 per cent ; thus, it might be unwise to push the speeds of turbo-prop machines too high.

# Effect of Interrupted Loading on Mechanical Properties of Metals*

By E. W. EVANS, B.Sc., Ph.D.†

No. I

*It is found for a range of metals that increased elongation to fracture may be obtained in tensile tests if the specimen is repeatedly loaded and unloaded, the strain increasing by small increments in each cycle. Extra elongation results only if cyclic loading commences at or prior to the point of maximum load on the load/elongation curve. It is appreciable only if the strain increment is small and it increases with the strain rate. The correlation of the effect with the hysteresis behaviour of the metals has been attempted with some success. Though Erichsen and Bulge tests on mild steel and α-brass sheet showed no increased ductility, cyclic loading may improve drawing or pressing practice through better lubrication.*

WHILST extensive work is being done on the phenomenon of fatigue, which involves cyclic application of tensile and compressive stresses in the elastic range, little is known about the effects of repeated loading on the plastic range, where the strains are much larger. Interest in this problem of cyclic plastic straining was aroused by the publication of a patent specification,[1] which claimed that metal deformation could be facilitated by tool vibration, the frequency of vibration suggested being of the order of $10^4$ cycles per minute. The mechanism suggested for this effect was twofold, viz. (*a*) a reduction of mechanical friction at the interface between tool and workpiece, and (*b*) a decrease of the internal friction in the structure of the material. It was further claimed that, instead of being concentrated over a small region of the material near the tool face, the deformation occurred more uniformly throughout the worked material. This specification suggested that here was a process much needed in the metal working industry, where small increases in ductility facilitate forming processes. Very little information was forthcoming from the patent specification and it was decided to investigate the effect of repeated loading in the plastic range on the mechanical properties of metals, with special reference to ductility.

Very little work has been carried out on this problem. Chaston,[2] in a note on the effect of interrupted straining on the elongation of lead, showed that large elongations (up to 300 per cent of the original gauge length) could be obtained under certain cyclic testing conditions. These large elongations were obtained by the repeated application of a load, increasing the strain by small increments in each cycle; the following factors were found to govern the amount of the extra elongation to fracture: (*a*) increasing the rest period at no load increased the elongation, (*b*) maximum extra elongation was obtained for an elongation increment of 0·8in in each cycle, and (*c*) increasing the testing rate increased the elongation. No extra elongation was obtained for large grain size material.

The author's suggested explanation was that during the rest period under no load there was grain re-orientation which brought their planes of easy slip parallel to the direction of elongation. In the discussion several mechanisms were suggested for the observed effects, the most favourable being based on the work of Norbury,[3] who showed that cold work can reduce the recrystallisation temperature of lead to below room temperature. The only aspect of Chaston's paper that remains to be discussed is the appearance of the tensile specimens at fracture. In contrast to the normal fracture of a bar tensile specimen, which occurs at the point where necking commenced, Chaston's specimens show a number of necks whose progress has been halted before fracture. This implies that a normal neck develops, hardens, and gives place to a second neck at some other point along the gauge length. The process is repeated until the stress is raised sufficiently to counter the extra hardening effect. The significance of Chaston's work in this investigation will be appreciated later.

Baldwin and Beiser,[4] investigating the cold heading properties of stainless steel, have shown that the deformation pattern affects the cold heading limit. The brittleness of the steel rapidly increases with forming speed, and they find a maximum in the ductility for a rest period between blows (in the multi-blow design) of four minutes. Moreover, the number of blows and the extent of the deformation in the first blow, markedly affect the ductility. Wallace[5] has shown that the maximum extrusion pressure is considerably decreased when the extrusion is carried out by three or more impacts. The rest period between blows is stated to have been long enough to permit the extrusion and tools to cool to room temperature. Here the difficulty is to determine to what extent the decreased pressure is due to metallurgical differences in working and to what extent it is due to enhanced lubrication. It must be pointed out that hydrodynamic lubrication is promoted by an increase in viscosity (lower temperature), provided the lubricant supply is constant.

These investigations did seem to suggest that repeated loading would affect the mechanical properties of a metal, and it was decided, therefore, to investigate the effect of interrupted loading on the normal, or continuous, tensile test.

## Experimental Procedure

(*a*) *Materials Used and Specimen Preparation.*—Mild steel, a high carbon steel, α brass, aluminium and copper have been investigated and the analysis, grain size, &c., of the materials used are given in the Appendix. Mild steel round specimens were machined from the bar to twenty or thirty thousandths of an inch oversize, annealed at 910 deg. Cent. for thirty minutes and slow cooled before finishing to size, care being taken with the last two cuts to avoid surface work hardening. Annealed steel and brass strip specimens were milled in a jig to within a few thousandths of the required width and finished by filing each strip individually. The round specimens had a tolerance of better than ±0·0005in, and the strip specimens better than ±0·001in on an 8in gauge length. The commercial purity aluminium rod used was annealed after machining, at 400 deg. Cent. for one hour in an air circulation furnace, and air cooled. The copper wire was annealed at 450 deg. Cent. in a protective atmosphere for one hour after a light pass to straighten the wire.

Stress concentration at the limits of the gauge length was avoided by using large radii, merging the ends smoothly into the parallel. Flash was removed from all edges of filed specimens and care was taken to ensure that specimens were not cold worked prior to testing. In the course of the work several different gauge lengths were used, and it was found convenient to mark the limits by lines scribed in a layer of quick-drying paint. Round specimens were made with parallel lengths either 8in by 0·564in diameter or 4in by 0·300in diameter; for strip specimens the parallel portions were 8in or 4in long and 0·724in wide.

(*b*) *Test Procedure.*—Most of the tests were carried out using an Avery Universal testing machine that was operated hydraulically, though some tests were made on a pendulum tensile testing machine of smaller capacity and others on a hydraulic Amsler machine. On all three machines there is provision for varying the strain rate and the load may be released to certain values, which may be maintained indefinitely, using a "dwell" device.

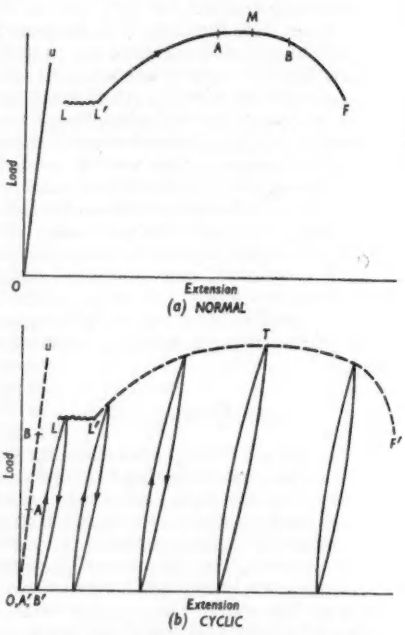


Fig. 1—Difference between testing methods

Several normal tensile tests were carried out on all the materials, and the load/elongation curve was usually determined by noting the load at given amounts of elongation. The elongation was measured by means of a Hilger cathetometer focused on the fiducial mark on the specimen nearest the cross-head of the machine: movement of the fiducial mark near to the fixed head of the machine was very small and was ignored in measuring the elongation. The total elongation was found from the measured gauge length before and after testing. The method of cyclic testing used required that the specimen be repeatedly loaded and unloaded, the elongation being increased by constant small increments during each loading cycle. The specimen was completely unloaded after each strain increment, or it was

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† Formerly an Investigator in the Metal Working Laboratories, Sheffield, of B.I.S.R.A.

unloaded to some constant low value in each cycle. The method is best illustrated by reference to Fig. 1.

In a continuous test, the load is applied until the specimen fractures, the load increasing to the U.T.S. and then decreasing to fracture. In the cyclic loading tests, the specimen is loaded (OA), until a small elongation has occurred (say ½ per cent of the specimen gauge length), when the specimen is unloaded (AA′) to A′, which may be zero or some positive value of load. The load is re-applied (A′B), until a further equal elongation increment occurs, when the specimen is unloaded (BB′). This procedure is repeated until the specimen fractures, at F′. It was found convenient to use elongation increments of the order of ½ per cent in each cycle—this corresponds to a ½ per cent strain increment per cycle for a 10cm gauge length, with about 60 cycles to fracture in a mild steel specimen of this length.

The equivalent of the normal load/elongation curve could be plotted by recording the maximum load in each cycle and plotting this against the elongation as given by the microscope. The response of the load indicators on both machines was rapid, so that there was no delay between application of a certain load to the specimen and the registration by the gauges. This is important to note, since the existence of such a delay might have misled us into assuming a general lowering of the load-elongation curve.

(*c*) *The Modified Avery Machine.*—The hydraulic Avery machine was modified for

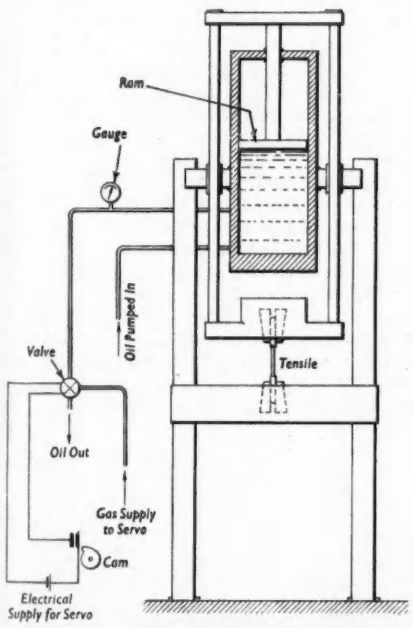


**Fig. 2—The modified universal testing machine**

some tests, as shown in Fig. 2, by inserting a solenoid controlled release valve in the pipe returning oil to the reservoir of the machine. By allowing the machine to pump oil at a steady rate into the cylinder and triggering the release valve when the cross-head had moved through small fixed distances, the loading/unloading cycle could be obtained. An adjustable make and break, actuated by a cam, in the solenoid circuit of the valve enabled its opening and closing times to be controlled to within fairly wide limits. When not opened by the solenoid current this valve was kept closed by gas pressure. The load was not given by the machine dial, which was by-passed, but by a Bourdon gauge in the return pipe, between the cylinder and the return valve; the response of this gauge was very rapid and enabled one to follow the load variations. Since the Bourdon gauge measured oil pressure in the cylinder it was necessary to calibrate it against the machine gauge in order to obtain the true load on the specimen.

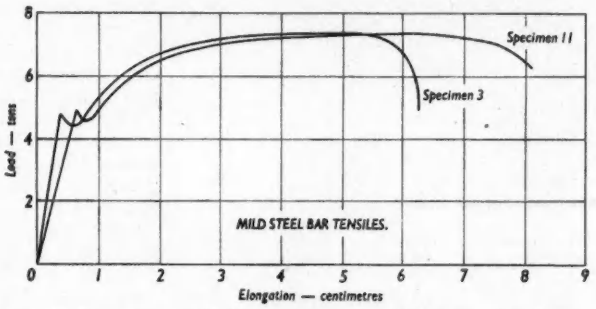


**Fig. 3—Comparison of load/elongation curves for normal (three) and cyclic (eleven) loading**

## Experimental Results, Part I

Certain quantities in the cyclic tests were variable, viz.:

(*a*) The number of cycles to fracture, i.e. the strain increment per cycle.

(*b*) The extent to which the specimen was unloaded in each cycle.

(*c*) The point on the load/elongation curve at which cyclic loading was started.

(*d*) The rate at which the specimen was loaded and unloaded.

(*e*) The rest period in the unloaded state.

The first metal to be investigated was mild steel, the main object of the tests on non-ferrous metals being to determine whether the effect was confined to a strain-ageing material or whether it was an effect general to all metals.

*Mild Steel.*—Typical load/elongation curves for mild steel bar and strip specimens are given in Figs. 3 and 4, which show that

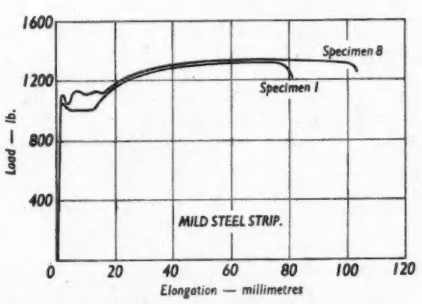


**Fig. 4—Comparison of load/elongation curves for normal (one) and cyclic (eight) loading**

neither the yield point nor the maximum load is changed by cyclic as opposed to static testing methods. Indeed, the load/elongation curves are identical up to the region of maximum load, where they diverge, the cyclically loaded specimen (11) continuing to deform at constant load, whereas the load decreases for the static tested specimen. The main difference between the two methods of testing is that cyclic loading results in considerable extra elongation to fracture. There was little scatter in the values obtained for the total elongation under any given set of testing conditions. The elongations were measured, after fracture, to the nearest ½mm, and scatter in the results of tensile tests was usually of the order of ±1mm.

Examination of the specimens after fracture showed that the mode of fracture in both the

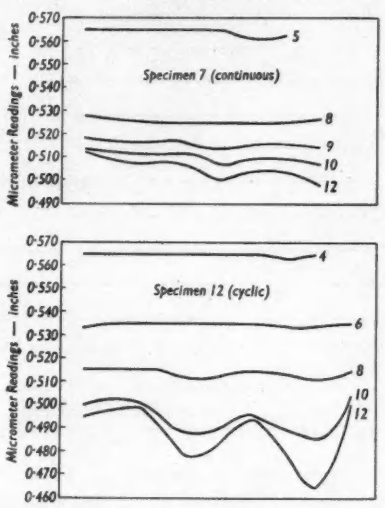


**Fig. 5—Profiles of bar tensiles during deformation**

cyclically and statically tested specimens was identical—both showed pronounced necking and the fracture was of the usual type; the fracture strain, as given by the diameter of the specimen at the fracture, was the same in both cases. However, diameter and width measurements made along the round and strip specimens during test and after fracture showed that the mode of deformation was different for continuously and cyclically tested specimens. As is shown by Figs. 5 and 6, there is evidence that multiple necks form in the cyclic loading, but not in the continuous tests. Also, as shown by the plots, uniform deformation proceeds further in the cyclic test, and it is considered that these two effects indicate a certain difference in the mechanism

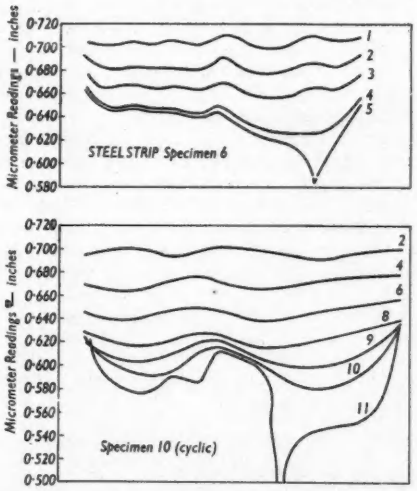


**Fig. 6—Profiles of strip tensiles during deformation**

of deformation. The significance of these results will be discussed later, when a general explanation of the phenomenon is sought.

Figs. 7 and 8 summarise the results of tests on the mild steel specimens, and indicate some of the factors that affect the total elongation to fracture.

(*a*) The extra elongation increases with decreasing strain increment per cycle, though

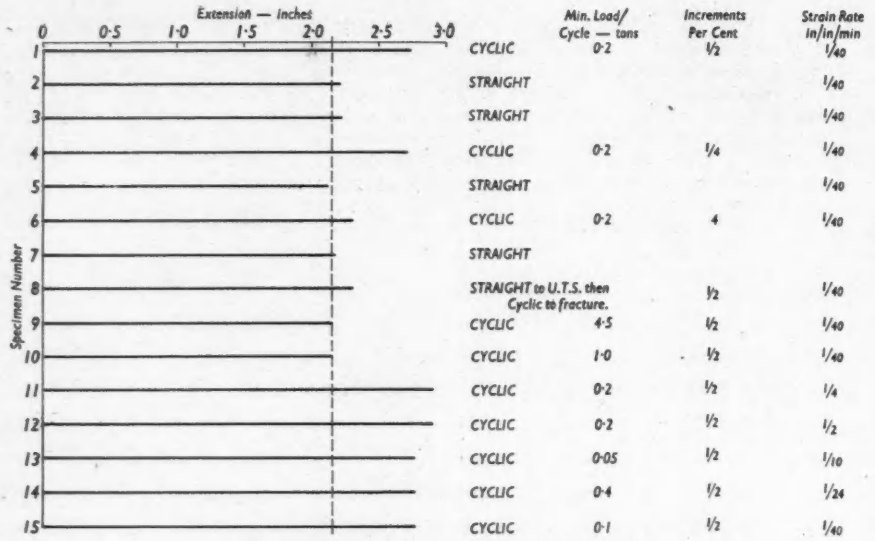
Extension — inches
0 0·5 1·0 1·5 2·0 2·5 3·0
Specimen Number
Min. Load/ Cycle — tons
Increments Per Cent
Strain Rate in/in/min
1 CYCLIC 0·2 ½ 1/40
2 STRAIGHT 1/40
3 STRAIGHT 1/40
4 CYCLIC 0·2 ¼ 1/40
5 STRAIGHT 1/40
6 CYCLIC 0·2 4 1/40
7 STRAIGHT
8 STRAIGHT to U.T.S. then Cyclic to fracture. ½ 1/40
9 CYCLIC 4·5 ½ 1/40
10 CYCLIC 1·0 ½ 1/40
11 CYCLIC 0·2 ½ 1/4
12 CYCLIC 0·2 ½ ½
13 CYCLIC 0·05 ½ 1/10
14 CYCLIC 0·4 ½ 1/24
15 CYCLIC 0·1 ½ 1/40

**Fig. 7—Summary of results for mild steel bar tensiles**

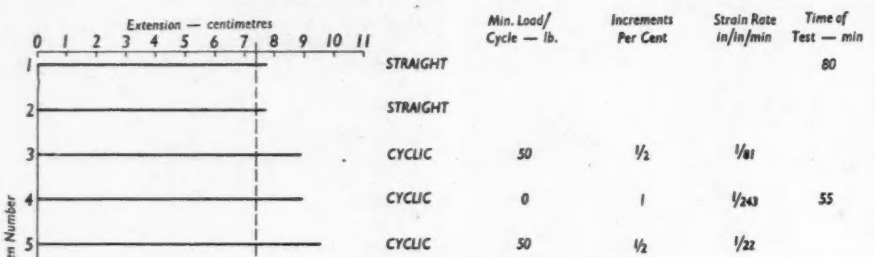
Extension — centimetres
0 1 2 3 4 5 6 7 8 9 10 11
Specimen Number
Min. Load/ Cycle — lb.
Increments Per Cent
Strain Rate in/in/min
Time of Test — min
1 STRAIGHT 80
2 STRAIGHT
3 CYCLIC 50 ½ 1/81
4 CYCLIC 0 1 1/243 55
5 CYCLIC 50 ½ 1/22
6 STRAIGHT
7 CYCLIC 100 ½ 1/22
8 CYCLIC 0 ½ 1/22
10 CYCLIC 1 min. rest at zero load ½ 1/22

**Fig. 8—Summary of results for mild steel strip tensiles**

operative at, or around, the point of maximum load, it was decided to investigate the effect of varying the point of initiation of there appears to be a limit to this effect. Comparison of the elongations given by specimens 1 and 6 (Fig. 7) shows that decreasing the increment size from 4 per cent to ½ per cent results in an increase in elongation by a factor of 3, whilst there is no difference between specimens 1 and 4 with ½ per cent and ¼ per cent increments respectively. Similarly, as shown by Fig. 8 for strip specimens, increasing the increment from ½ to 1 per cent (specimens 4 and 8) decreases the extra elongation considerably.

(*b*) The extra elongation increases with increasing strain rate. This is shown by specimens 1 and 11 of Fig. 7 and specimens 3 and 5 of Fig. 8. Specimens 1 and 11 were pulled at strain rates of 1/40 and ¼in/in/minute respectively, and specimens 3 5, at 1/80 and 1/20in/in/minute respectively.

(*c*) For a constant strain increment per cycle and constant strain rate, the extra elongation varies with the minimum load per cycle according to Fig. 9. There is a pronounced maximum in the curve for tests in which the specimen was unloaded to 0·2 ton. The normal elongation, shown by AA′, is given by specimens unloaded to 1·0 and 4·5 tons ; since the elongation is strain-rate dependent, points B and C would be lower had all the tests been made at the same strain rate of 1/40in/in/minute. This behaviour was confirmed, the strain rate being kept constant at ¼in/in/minute, and the results are plotted in Fig. 10. The total testing time was kept constant and the same for both static and cyclic tests. In this case there is a maximum in the same minimum load region as for the slower testing speed, but appreciable extra elongation when the specimen is unloaded to 4·5 tons in each cycle. Apparently at the higher strain rates the extra elongation is not so dependent on the extent of unloading in each cycle, and suggests that the extent of unloading is not as important as strain rate and elongation increment in determining the extra elongation to fracture.

For the mild steel strip specimens maximum elongation resulted when the specimen was completely unloaded in each cycle—see specimens, 7, 5, and 8 of Fig. 8.

(*d*) Table I gives the results of a number of tests on the modified Avery machine with different values of the variables frequency, strain increment, rest period at zero load, from which it is apparent that the test conditions have become unfavourable to the production of extra elongation. The main innovation was that the unloading period in each cycle had been extremely short, whilst the loading period remained unchanged.

TABLE I—*The Effect of the Unloading Period on the Extent of Extra Elongation. Mild Steel Bar Tensiles, 10cm Gauge Length × 0·300in Diameter*

| Specimen | Test time minutes | Details of tests | Elongation, mm |
|---|---|---|---|
| A | 15 | Static | 29 |
| B | 3/4 | Static | 28·5 |
| C | 3/4 | Automatic cyclic. 120 cycles per minute | 28·5 |
| D | 3/4 | Automatic cyclic. 120 cycles per minute | 29 |
| E | 45 | Hand cyclic. Load to 0 in 30 seconds | 33 |
| F | 3 | Automatic cyclic (85 strokes) rested 1 min after 65 strokes | 31 |
| G | 10 | Automatic cyclic (85 strokes) rested 1 min every 10 strokes | 32·5 |
| H | 7 | Automatic cyclic. 40 cycles per minute | 29·5 |
| | 30 | Automatic cyclic. 40 cycles per minute 25 rests of 30 seconds. | 35 |

The difference is best appreciated by scrutiny of the load/time patterns in Fig. 11; (*a*) being that for hand testing, (*b*) using the automatic method, and (*c*) using the automatic method in conjunction with rest periods when the specimen is unloaded. That too short an unloading time is the operative cause of no extra elongation has been verified by interposing rest periods at no load, which are seen to result (specimens G, I), in extra elongation. Specimen E, for which the loading and unloading was done by hand, showed increased total elongation to fracture.

(*e*) Since the form of the load/elongation curves suggested that the extra elongation was due to some effect that first became

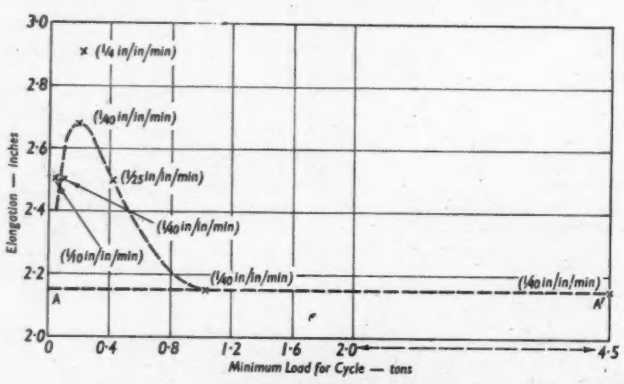


**Fig. 9—Effect of load relief on total elongation**

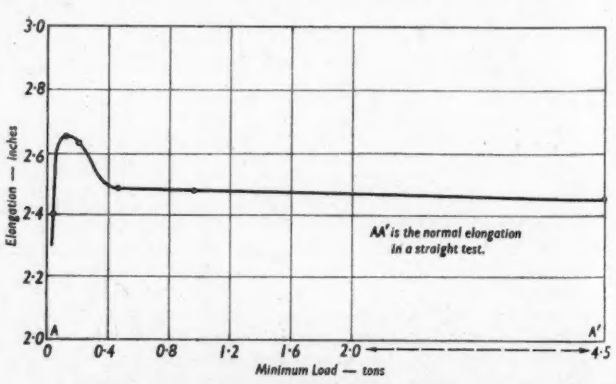
Elongation — inches
3·0 2·8 2·6 2·4 2·2 2·0
AA′ is the normal elongation in a straight test.
A
A′
0 0·4 0·8 1·2 1·6 2·0 4·5
Minimum Load — tons
Strain Rate = ¼in in min

**Fig. 10—Effect of load relief on total elongation**

cyclic loading. Mild steel strip specimens were loaded continuously to strains corresponding to points such as *A*, *M* and *B* (Fig. 1(*a*)), on the load/elongation curve before starting to load cyclically. That little elongation results if the maximum load point *M*

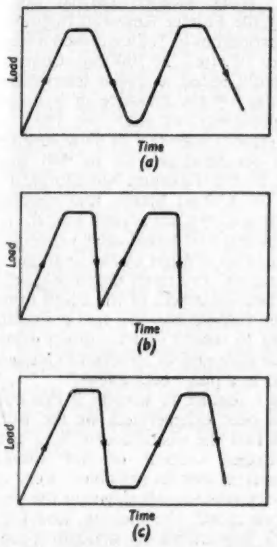


**Fig. 11—Load/time patterns for different tests**

is passed before starting to load cyclically is shown by Table II. Specimens pulled in tension to a point *A* just short of the maximum on the curve and then cyclically loaded to fracture yielded the same extra elongation as specimens subjected to cyclic loading throughout the test.

TABLE II—*Mild Steel Strip. The Effect of Straining to the U.T.S. Region Before Starting to Load Cyclically. Maximum Load in a Straight Test was at Between 30mm and 33mm Extension*

| Specimen | Details of test | Times of test, min | Length at fracture, cm |
|---|---|---|---|
| 1 to 6 | Straight | In the range 7–60 min | Mean = 14·4 ±0·15 cm |
| 7 | Cyclic | 40 | 15·3 |
| 8 | Cyclic | 70 | 15·05 |
| 9 | Cyclic | 100 | 15·3 |
| 10 | Straight to 25mm extension then cyclic to fracture | 30 | 15·0 |
| 11 | Straight to 30mm then cyclic to fracture | 30 | 15·15 |
| 12 | Straight to 35mm then cyclic to fracture | 19 | 14·6 |
| 13 | Straight to 35mm then cyclic to fracture | 21 | 14·65 |

(*f*) Effect of grain size. Mild steel bar tensiles were annealed at 1050 deg. Cent. for one hour and slow cooled to below the critical temperature. The mean grain diameter was approximately twice that for the normalised steel, pearlite occurring as large masses dispersed in the ferrite matrix. Though cyclic loading resulted in increased elongation to fracture, this increase was small even for the set of conditions that yielded the largest effects for small grain size material. Moreover, varying the load conditions did not affect the total elongation:

| Specimen | Details of tests | Strain rate, inches/inch/min | Total extension on 200 mm., mm |
|---|---|---|---|
| 2 | Straight | 1/40 | 61 |
| 4 | Cyclic (1mm increments) load→0·2 ton | 1/40 | 66 |
| 5 | Cyclic (1mm increments) load→0·05 ton | 1/40 | 67 |
| 6 | Cyclic (1mm increments) load→0·01 ton | 1/40 | 65 |

0·75 *C Steel.*—This steel was annealed at 850 deg. Cent. for one hour. No extra elongation to fracture was obtained in cyclic loading tests, and the load/elongation curves were identical for static and cyclic loading.

(*To be continued*)

# Titanium in the Aircraft Industry

*On Friday last a conference was convened by Imperial Chemical Industries, Ltd., to elucidate the prospects of titanium in the aircraft industry. There was widespread support for the view that formability, as evidenced by a high ratio of ultimate to proof stress, was more valuable than great strength, but some doubt remained as to the excellence of the fatigue resistance.*

A CONFERENCE on titanium in the aircraft industry was convened by Imperial Chemical Industries, Ltd., and attended by representatives of aircraft and aero-engine manufacturers, suppliers to the industry, and the Ministry of Supply, with the intention of discovering the nature and extent of probable applications and on which qualities development work should be concentrated. Dr. R. Beeching was in the chair, and the speakers, where not otherwise stated, were members of the I.C.I. Metals Division. Dr. Maurice Cook observed that titanium was not a rare metal, and that while the bulk of it came from the United States, some was being made in this country—using sodium as a reducing agent instead of magnesium—and in Japan. In 1956 total production was approaching 20,000-ton level and this year it might near 30,000 tons. The price had been nearly halved in the last three years and might be again by 1960. His opinion was that in ten years' time output might be about 100,000 tons, and the cost in fabricated forms approaching twice that of stainless steel, i.e. equality on a volume basis.

Mr. M. Clapham observed that the wrought forms of titanium were being produced at about 400 tons a year in this country and 500 to 600 tons a month in the U.S.A. The only other country with a large-scale industry producing wrought titanium was the U.S.S.R., but there were no figures of production there. Prices here were still higher than in the United States, but if present trends continued would become equal by 1959 or 1960. The price of raw granules now accounted for less than half the cost of fabricated products, even allowing for the very high process losses. The General Chemicals Division had been able to keep its price below that of American sponge, mainly because the sodium process which it had developed was inherently cheaper than the Kroll magnesium process. They had also been helped by having a guaranteed market: unlike the production of wrought forms, which was purely an I.C.I. venture, the production of raw titanium was backed by a Government undertaking to buy up to 75 per cent of the production of the 1500-ton plant at not more than the current world price. This guarantee had made possible economic production and provided a stockpile for the Ministry of Supply which would be valuable when—probably next year—requirements passed the output of the present plant. Some exports were envisaged by 1960.

Mr. St. J. Elstub outlined the policy of the firm in producing the wrought forms required by the industry: if it did not have the plant or experience to provide all the forms needed, arrangements would be made with other organisations. Bearing in mind the possibility of recycling scrap, raw material supplies would not be a bottleneck in a short-term programme, but major increases would need a new plant and additional sodium capacity. Progress in melting had been such that the same supply of electricity as provided 1500 tons of single melted material in 1955 would yield 1800 to 2000 tons of double melted ingots in 1958: I.C.I. had written off as obsolescent four sets of furnaces in four years. As a result of explosions that had occurred in the United States and his own research department, all furnaces were now situated in reinforced cubicles and remotely operated. Violent fluctuations of demand, such as in 1956, hindered the production of ingots. Up to the present all wrought forms had been produced on traditional plant, but the need for a specialised plant had been appreciated more quickly here than in the United States, and a new plant was in hand at Waunarlwydd in South Wales that would be ready to produce sheet by the middle of this year and rod by the end. They felt sufficiently confident of the process of rolling rod to install a Swedish automatic mill with roller guides and repeaters for finishing speeds over 2000ft per minute. While commercially pure material could be continuously rolled into strip or sheet, it was very doubtful that the strong alloys could be cold rolled at all. As a short-term solution, two very powerful four-high single sheet mills were being installed, one for hot and one for cold rolling. In collaboration with Shepcote Lane Rolling Mills, Ltd., techniques for strip rolling the pure material on Hot Steckel and Sendzimir mills were being developed. Casting was difficult, but simple shapes had been cast in graphite moulds.

Mr. J. R. Crane discussed the wrought forms now available: some of the alloys were those favoured in the United States, others had been developed by I.C.I. Because of the remarkable softness of material from the sodium reduction plant, all but the softest grades of commercially pure metal were hardened by additions of oxygen. All forged billets were ultrasonically tested before despatch. The new rod plant at Waunarlwydd would give stock from 5in down to ¼in diameter, centreless ground to sizes on a preferred number system. The small rod was mainly used for fasteners, and promising batches of bolts had been prepared in 314 A. Extrusion of complicated shapes was under development with some measure of success. Plate—over ⅛in thick—and sheet were at present limited to a maximum piece weight of 650 lb. Commercially pure sheet had originally been criticised in respect of flatness and gauge tolerances, but standards equal to those for alloy steel sheets for aircraft were now met: widths would rise from 2ft to 4ft when the plant in Wales was running. Alloys would need to be hot rolled, and development was aimed at sheets down to 0·010in. Narrow strip for honeycomb and heat exchangers was being produced down to 0·0025in and 0·001in might follow: alloys as well as the present commercially pure metal might come in strip form. Commercially pure metal yielded tubes performing like stainless steel and able to be bent and flared over a standard coupling cold. Stronger tubing, if desired, could not enjoy these advantages. There had been criticism of the 15-ton range of u.t.s. on commercially pure metal: within three months this should be reduced to 12 tons, corresponding to United States practice, and when new furnaces were in action possibly to 10 tons. They suggested that of the present four grades of commercially pure titanium, 150, 35–50 tons u.t.s., be abandoned in future. The doubtful homogeneity of early titanium had led to extravagant testing—one set of tests per 150 lb, or four per ingot—and it was hoped to reduce this. Any further testing desired by the customer would have to be paid for.

These four addresses were followed by a discussion, opened by Mr. Cuss (Gloster Aircraft Company), who pointed out that minimum values of 1 per cent proof stress were specified, but that maximum values were more valuable if lack of ductility was not to be obtrusive, and if there was to be some warning of a structure being overloaded. Dr. N. P. Inglis observed that high strength alloys generally had proof/ultimate strengths in the ratio 0·8 to 0·9. For titanium alloys of 70 to 80-ton strengths, he anticipated no amelioration, but in the lower strength ranges an improvement could be brought about. Mr. Elstub pointed out that the difficulty in forming titanium of high yield strength could be eased by working at about 400 deg. Cent. Mr. Tinson (Dowty Group) raised the question of reclaiming scrap. Mr. Elstub replied that while I.C.I. used some of its own scrap, it could not yet accept that of its customers, but in five years' time scrap that had a completely known history might be bought.

In ten years titanium would doubtless be treated like other metals in this respect. Mr. Clapham remarked that scrap had been sold to firms in the United States for electrolytic recovery, and people were "squirrelling" it away against the time when it would be usable.

Mr. Marshall (Electro Hydraulics) drew attention to the poor resistance of titanium tubes to fatigue caused by pulsating pressures, which, Mr. Crane pointed out, was due to mechanical rather than metallurgical defects. Dr. Inglis went into greater detail, attributing the flaws to the tendency of the material to gall in a die. A process of extruding a shell and removing the surface material, both inside and out, held promise of success, prototypes having proved good for a few million cycles of pressures up to 5000 lb per square inch. Mr. A. D. Keen (Armstrong Whitworth Aircraft) detected complacency in the reference to titanium sheet as accurate as stainless steel—that was not good enough for aircraft purposes, for which tolerances such as prevailed for light alloy were wanted; Mr. Crane explained that such standards were being striven for. Mr. McLean (Short Brothers and Harland) wanted to see a better surface, particularly on 318A. Mr. Crane pointed out that the matt finish of commercially pure metal was due to descaling, and said that in the South Wales plant continuous annealing would cause less oxidation and result in a better surface. The alloys would have to be rolled hot and, therefore, suffer oxidation, and the removal of the layer of oxygen-enriched metal gave rise to pitting. There were three approaches to this problem: to evolve a descaling process that did not cause pitting, to confine hot rolling to the early stages of forming and finish with, say, planishing, or to roll the late passes in an atmosphere of argon.

### Research and Development

Dr. N. P. Inglis observed that the Metals Division was spending the order of £250,000 each year on research into alloying and processing of titanium, excluding refining. There follow abstracts from his words.

*Development of High-Strength Alloys, Particularly Sheet Alloys.*—Much research is in progress, both here and in the United States, with the objective of evolving high-strength alloys, and particularly alloys which can be produced in sheet form to possible future aircraft requirements.

Our principal research in the alloy field at this moment is an intensive search for a relatively soft alloy which can be hardened very considerably by heat-treatment. A target to be aimed at is 40 tons per square inch for the material in the annealed condition, rising to, say, 80 tons per square inch, after suitable heat-treatment, plus, of course, the additional requirement of reasonable load-carrying ability at 300 deg./400 deg. Cent.

We should be able to say fairly definitely before the end of this year whether or not an alloy of the type we are seeking is likely to be forthcoming.

Whilst following our own research methods as outlined above, we are keeping a close watch on developments in the United States.

Nearly all the new alloy compositions recently advanced in the U.S. are for alloys of the alpha-beta type, and most of them have been devised primarily for the gain in strength which should be achievable by heat-treatment. A number of alloys have been put forward by the American Department of Defence for an intensive evaluation of the production and properties of these alloys in sheet form. Presumably, those selected have been based on previous laboratory work. The intention of the U.S. Government project is to roll relatively large quantities of each alloy, perhaps 20,000 lb, for complete evaluation on a production basis.

All the alloys contain aluminium, presumably because of its low density and its beneficial effect on elevated temperature properties. One also notes on looking at any recent American alloys that manganese, once a favourite alloying addition, now seems to have fallen very much in favour. We believe that there are good grounds for avoiding manganese as a beta stabilising element because its presence undoubtedly gives rise to difficulties of control of composition in vacuum melting and its relatively high reaction rate gives rise to embrittlement during welding. Vanadium, molybdenum, niobium and tantalum are, at the moment, the favoured beta stabilising additions.

The strength achieved by these new alloys, even in the heat-treated condition, is not higher than that which can be obtained with existing established alloys. One must assume, therefore, that the immediate objective in mind in the U.S. in working on these alloys is to provide material of at least equal strength to the established alloys, but with easier fabrication and manipulation properties. Relatively low strength in the softest condition, with high strength and stability in the heat-treated condition are obviously very desirable characteristics. Improved strength-ductility relationship, lower solution heat-treatment temperatures, and better reproducibility in properties might well give some of these alloys very great advantages over existing ones. Then, again, as is so usual in devising alloy compositions, a certain degree of compromise between different properties is often desirable. Thus, one might have to compromise in order to obtain an alloy with a reaction rate sufficiently high to give high strength with practical heat-treatment conditions, but slow enough to permit welding without embrittlement.

An American alloy containing 15 to 16 per cent vanadium with 2½ per cent aluminium perhaps deserves particular comment, because in the soft condition it not only has an ultimate tensile strength of below 50 tons per square inch, but it has a particularly low yield stress which should be a very great advantage in rolling, forming and manipulating generally when in this condition. It is claimed that by using solution heat-treatment temperatures in the alpha-beta field this low yield strength is retained in the solution heat-treated condition, but after ageing relatively high yield and ultimate strengths are attained. Work has been done on this alloy by R.A.E., who solution treated in the beta field, whereas U.S. workers claim better results by solution treatment in the alpha-beta field.

Very recently, Mallory Sharon has put forward an alpha-rich alpha-beta alloy containing 8 per cent aluminium, 2 per cent niobium, and 1 per cent tantalum, which, it is claimed, is a highly weldable sheet and bar alloy, possessing good high temperature strength and good formability. These claims might well be justified since the high aluminium content should give good high temperature strength and the relatively low hardenability should be advantageous in welding, although, of course, it would naturally limit the ultimate strength possible. In actual fact, the claims for ultimate tensile strength cover 67 tons per square inch with 10 per cent elongation, using a solution heat-treatment temperature of a little over 1000 deg. Cent. Although Mallory Sharon has been the first to give publicity to this alloy, it is, in fact, an alloy for which we ourselves filed patent application as far back as 1953.

Another alloy arousing some interest at present in the United States is one containing 7 per cent aluminium and 3 per cent molybdenum. Our own preliminary evaluation of this alloy suggests that the strength characteristics at 400 deg. and 500 deg. Cent. are considerably better than other alpha-beta alloys, such as 314A and 318A, although, of course, not as good as the alpha alloy 371.

*Hydrogen.*—A very great deal has appeared in the literature regarding the effects of hydrogen in titanium and titanium alloys, but the exact position in regard to this question is by no means clear.

A great many types of tests have been devised which do seem to give results depending on the hydrogen content of the metal, but the significance of these tests from the point of view of practical behaviour in service is by no means clear. In fact, despite the very considerable publicity and discussion on this matter, the number of well-authenticated cases of failure which can be quite definitely ascribed to hydrogen is extremely small.

It has been fairly well established by workers at Battelle and elsewhere that two types of hydrogen embrittlement may occur in titanium-base materials, namely, embrittlement during rapid straining due to the presence of hydride particles in commercially pure titanium and some alpha alloys, and also embrittlement during slow straining which occurs in the absence of visible hydride in alpha+beta alloys. In this latter case, the embrittlement during slow straining in alpha+beta alloys was not found with hydrogen contents less than 200 parts per million. Work recently carried out on our behalf by the Fulmer Research Institute showed that the properties of 314A exposed under various conditions of stress at 300 deg. Cent. and then subsequently tested at room temperature, were not affected by the presence of hydrogen, even at concentrations as high as 330 parts per million, either under fast or slow straining rates. Tests at temperatures up to 540 deg. Cent. reported by the Titanium Metallurgical Laboratory in the United States, and covering three alpha+beta alloys, did suggest that the reduction in area of material tested after exposure to such conditions was affected by the hydrogen content, but the report very fairly emphasises that variations in heat-treatment of the alloys tested might have been responsible. In this connection, it is important to record that no direct evidence has ever been obtained of structural changes due to hydrogen in alpha+beta alloys.

Whilst I venture to wonder if this bogey may not have been exaggerated, we are working on the basis that the wisest course is to ensure that the hydrogen content of our titanium-base materials is as low as possible. Very considerable care is taken at all stages in the production of the raw metal, the melting, and the various stages of fabrication to wrought products, to prevent hydrogen pick-up. This has necessitated a very great deal of attention being given to furnace atmospheres, methods of descaling, &c. The alternative to strict hydrogen control during processing is vacuum degassing of the final product, and much thought is being given to this, but it will undoubtedly be expensive and will be distinctly restrictive in regard to types of heat-treatment which it might be desirable to employ.

In addition to taking these very strict practical steps to reduce hydrogen content, we attach very great importance to establishing a thorough understanding of the problem. In addition to work in this field which is being done in our own research department, we have sponsored fundamental work at the University of Birmingham.

*Discussion.*—Mr. Rochford (Hawker Aircraft) referred to the 318A material and observed that he had not been able to reproduce the quoted behaviour. This did not distress him, but he did object to it being impossible to work the metal cold, and reiterated that the maximum proof stress should be specified. In the United States solution treatment had been found to improve the proof/ultimate stress: was it the case that 0·75 had been obtained?

Miss McQuillan observed that a low proof/ultimate ratio was not a characteristic of titanium, but of high strength alloys. It so happened that, while the ideal was for the interstitial elements to come into action at progressively higher stress levels, in titanium all the strengthening mechanisms acted at the same level. Either these interstitial elements must be kept out, or a different method of deformation be employed, for example, a Martensitic alloy, rich in beta phase. Only in certain well-defined cases would it be possible to establish a high ratio between proof and ultimate strengths.

Mr. Marshall (E.—H.) queried the desirability of the hexagonal lattice: Miss McQuillan assured him that the material was not analogous to magnesium, being markedly more ductile. Mr. Crane, taking the case of 318A again, pointed out that heat-treatment could reduce the proof stress, but not without sacrifice of a 62-ton ultimate.

Mr. Howard (Ministry of Supply) considered that commercially pure metal should be limited to a 40-ton grade, and Mr. Sandifer (Handley Page) was largely in agreement: formability was the principal requirement of sheet—the material was costly enough, without the burden of working it hot. On a forging in 314A a proof stress 98 per cent of ultimate had been observed; such a material could never be used in a redundant structure. He would be quite satisfied with an ultimate strength of 60 to 65 tons if the proof did not exceed 85 per cent of this. He

suggested that commercially pure metal be confined to 130 and 160. Mr. King (English Electric) supported these views, saying that the airframe industry was unanimously in favour of sheet with a 371 specification suitable for cold working.

Mr. Barker (Firth Brown) regarded proof stress and elongation as the important parameters; on austenitic steel a low value of proof/ultimate strengths could be accompanied by poor elongation and better ductility by a high value of proof/ultimate. He inquired whether there was known to be a correlation of this nature. Dr. Inglis thought not; if a greater ratio of proof to ultimate was wanted, it would be provided at the expense of ultimate strength—but the material would never work like aluminium. Mr. Hall (Rolls-Royce) pointed out that sheet to 317 or 318A could readily be used from drum-shaped objects, but parts that needed to be pressed were more difficult. For engine manufacture there was a need for a precipitation hardening alloy which would be aged after fabrication. Where compressor discs and similar components were concerned, an alloy that did not demand a drastic quench was wanted: the material was costly, the utilisation down to 10 per cent, and distortion must be minimised—the ability to cool in air would be welcomed. He added that his firm had used titanium compressor blades without a failure for three or four years.

### Applications

Mr. R. L. Preece analysed 1956 sales as follows:—(1) 40 per cent rod for compressor blades; (2) 20 per cent sheet for firewalls; (3) 20 per cent sheet for exhaust and jet pipe shrouds; (4) 5 per cent billet for discs and spacers; (5) 5 per cent bar for small forgings.

In the first category, limitations to more extensive use were of temperature rather than strength; it was desired to use the same stresses at higher temperatures. However, the manufacturers might try developing methods to use tougher alloys than the 40 to 55-ton materials at present in use.

For firewalls it appeared that wider, thinner sheet to substitute for stainless steel was wanted; for the shrouds formability was called for, and commercially pure materials were adequately strong.

Titanium alloy discs and spacers demanded creep resistance and heat-treatments for 371 suitable for thin sections were being sought; assembly by welding might avoid the difficulty of forging to thin sections.

The use of tubes was awaiting enhanced fatigue resistance. Problems associated with galling were holding back some uses, but various surface treatments such as oxidation, anodising, possibly cyaniding, electro-plating or chemical deposition might help overcome them.

Dr. H. W. Shaw examined the value of weight saving in a commercial aircraft. Considering only the increase in payload possible over ranges beyond that to which the maximum payload could be carried, he estimated 1 lb of weight to be worth a yearly profit of from £17 to £22 on short sectors to £70 to £80 on extremely difficult routes. The cost of saving weight by means of titanium was not yet established, but in batch production it might be £20 per pound. Where stressed components were concerned, fatigue life in service might override economic considerations, and because of the cost of the material welded components might be expected to emerge.

Mr. Boorman (Short and Harland) favoured a reduction in the number of specifications, and disliked the present system, whereby suffixes could be called on to differentiate quite different materials.* While titanium was a favoured material for supersonic aircraft, a wing spar box for a subsonic design had shown a weight saving of 14 per cent in titanium. However, torsional rigidity was down—was a higher Young's modulus attainable? He shared the view that hot forming was insupportable.

Mr. R. L. Lickley (Fairey Aviation) observed that his firm made little or no use of titanium, largely because the specifications could not be guaranteed and the consistency was not close enough. Two commercially pure grades and an alloy of 60 to 65 tons, with a proof strength not more than 80 per cent of this, would be satisfactory.

Mr. Smyth (Aviation Traders) said that a high value of proof/ultimate strength was associated with bad fatigue life in aluminium. A badly fitting rivet allowing fretting corrosion to take place had been known to reduce the life of a specimen by a factor of eight; was titanium subject to fretting corrosion? Whether aircraft were designed on safe life or fail-safe principles, long fatigue lives for components were essential if the operator was to show a profit, and the question was whether titanium would excel aluminium in this respect. Dr. Inglis knew of no relationship between fatigue and the proof/ultimate ratio; there was none for titanium. The high corrosion resistance of titanium did not render it immune from fretting corrosion, and cases of the latter had occurred, but no tests had been done. Treatment with an anti-galling compound might be beneficial in practice.

Major P. L. Teed (Vickers-Armstrongs) asked for comments on the confused and contradictory literature concerning the effect of hydrogen. Since stress concentrations were inevitable, he considered fatigue results on smooth test pieces meaningless. Fretting was the first stage in stress corrosion, and he considered the liability of titanium to fretting critical. Dr. Inglis pointed out that hydrogen contents were now well below the levels at which adverse effects had been observed (see above, "Research and Development") being 100 to 130 parts per million. He did not consider fretting corrosion to have been established as a mechanism of failure; it was possible that the galling or tearing to which titanium was susceptible accelerated fatigue.

Mr. Clarke (De Havilland Engine), said that the creep performance of titanium alloys was dubious, because the stability of the material at high temperatures was not established. Because it might result in a material unstable at 400 deg. Cent., he did not favour quenching 371. Dr. Rodgers pointed out that 371 was in the alpha phase and there was only very doubtful evidence that instability could be observed; incorrect quenching might have caused suspicious behaviour. Quenching was necessary for the best creep resistance, but an alternative technique, recovery from hot working, was sought.

* A three-figure number is allotted to each grade or alloy, the first figure of which indicates how many elements are present in appreciable quantity. Thus the numbers 100 to 199 are used for nominally pure titanium, the numbers 200 to 299 for binary alloys, 300 to 399 for ternary alloys, and so on. In distinguishing grades of nominally pure titanium a series of numbers has been allotted, an increase in number corresponding to an increase in hardness and strength. The softest grade possible, i.e. iodide titanium prepared by the van Arkel process, would be termed titanium 100, while the numbers 120, 130, 150 and 160 have been given to successively stronger grades of commercial purity. For titanium alloys the last two figures indicate the two main alloying elements, thus: (1) aluminium, (2) chromium, (3) iron, (4) manganese, (5) molybdenum, (6) silicon, (7) tin, (8) vanadium, (9) zirconium. Titanium 240 would, for example, denote a binary titanium-manganese alloy, titanium 314 a ternary titanium-aluminium-manganese alloy.

# The Fairey "Delta 2"

By R. L. LICKLEY, B.Sc., F.R.Ae.S., and L. P. TWISS

*On February 14 this joint lecture was given to the Royal Aeronautical Society. We reproduce here the first part of the lecture, read by Mr. Lickley, devoted to design and construction.*

THE development of manned supersonic aircraft in this country suffered a setback at the end of the 1939–45 war, when it was decided that the use of manned aircraft would be too dangerous; however, more realistic views soon prevailed and, as a result, the ordering of such manned aircraft was considered in 1947 by the Ministry of Supply, and in our submissions to M.o.S. in 1949, we described the aircraft as having as its primary function "Research Flying at Transonic and Supersonic speeds up to M=1·5."

The background which led up to this submission is of interest, as it shows a logical line of development within the company.

In 1947, the company was developing the "F.D.1." at Stockport and scale models of it at Heston, in order to conduct vertical take-off experiments. The models were of advanced design, propelled by a rocket motor with twin combustion chambers controlled in pitch and yaw respectively by an automatic pilot. Information of behaviour in flight was telemetered to the ground.

In September, 1947, the company was asked if it could further develop the vertical take-off models to fly transonically after ground launching as part of the experimental programme. After consideration it became clear that, although the technique and experience of the V.T.O. models would be of great value, the experiments themselves would be of little use unless they were aimed at obtaining specific information on a layout representative of a typical possible piloted supersonic aeroplane. We, therefore, began a design study of such a piloted aircraft as a preliminary to the design of the pilotless models. Our first efforts resulted in a design of high sweepback on both leading and trailing edges, all-moving tip ailerons, conventional tailplane and twin engines in the fuselage fed from a nose intake ("P.1" layout).

This design was not proceeded with, but in February, 1949, we were approached by P.D.S.R. (A) (then Sir Harry Garner) and asked to consider an alternative design for a further supersonic research aircraft, preferably based on a single engine. We had, of course, by this time considerable background in the problems of designing such an aeroplane. We had developed the necessary new techniques of drag and performance estimation and had collected together what slender information there was on the stability and control characteristics of various configurations. We decided to begin our considerations afresh and, by the end of the year (December, 1949) had come to a firm proposal which differed very little from the aero-

Fig. 1—Aircraft with nose drooped

plane as it is flying at present, although pressure from various sources to make changes was at times very strong.

The design which evolved was a delta-wing plan form of aspect ratio 2, having a Rolls-Royce "R.A.5" engine in the body with wing root intakes with frontal areas cut to a minimum and all possible excrescences removed. The major target and guiding principle in the whole design period was to get an aeroplane of minimum weight, with the smallest frontal and surface areas, while still remaining a straightforward aeroplane to handle in the air and on the ground, and yet at the same time large enough to house the "R.A.5" engine and sufficient fuel to enable worthwhile flights to be made. As an indication of the design problems raised by this approach, the maximum clearance between engine and fuselage skin is less than 6in and within this space room had to be found for the main frames to which the wing is bolted.

Although the aerodynamic form was decided at an early period, the contract to build two aircraft was not placed until October, 1950; lack of money, priorities and other problems caused this hold up and almost immediately after the placing of the contract "super-priority" intervened and the need at Faireys to concentrate on the "Gannet" meant that a fully effective start was not made on the design work until the summer of 1952, and manufacture effectively began about the end of that year.

Little or no priority was given to the aircraft and, because of the demand on wind tunnel capacity for tests or service types under development, only very meagre and belated high-speed tunnel tests had been undertaken before the aircraft flew. In fact, some supersonic tests were only analysed after the aircraft had flown supersonically.

With that introduction, we can now consider the main features of the design.

## Aerodynamic Design

(1) *Moderate Wing Loading*.—This was chosen to give good high-altitude performance, medium landing speeds and good performance from normal length runways.

(2) *t/c Ratio*.—This, at 4 per cent, is still one of the lowest flying and at the design date (1949), was the lowest known.

(3) *Tailless*.—The advantages of this layout were held to outweigh the reputed disadvantages and, when one considers the various tail layouts to be seen to-day, and the established need for fully variable tailplanes, the choice seems to have been the correct one, possibly more than anything else, because of the aerodynamic simplification produced.

(4) *Intakes*.—Side intakes were decided on, as it was felt that the structural simplicity and saving in weight, compared with a nose intake, were worth more to the design that the possible aerodynamic difficulties introduced. At various times the intakes were the subject of strong criticism, both from the aerodynamic aspects and from the possible bad effects on compressor flow, but they have remained substantially as initially conceived, and have proved satisfactory up to the highest Mach numbers reached.

(5) *Large Chord Controls*.—Much discussion has ranged round trim drag and the penalties it applies to delta aircraft. Our thinking led us to believe that much of the drag could be avoided by careful design and, in particular, by the use of large chord controls which would keep the angular movements reasonable. So far, our only problem with these controls has been lack of jack effort in certain flight cases; as predicted, the effects of trim drag have not been serious.

(6) Mathematically defined forms were used for aerofoils and fuselage, to enable high accuracy of contour to be attained in the final manufactured product.

(7) *Dive Brakes*.—These, of petal form, at the rear of the fuselage, were designed to give minimum change of trim, &c., and in flight at sub- or super-sonic speeds have given no pitch or lift changes and more than adequate deceleration.

(8) *Body Form*.—Considerable work was done on this and it might be described as an early approach to area rule—the short intake fairings (inspired by Küchemann) combined with a cylindrical body to the trailing edge and the swept-fin mainly behind the trailing edge.

These, briefly, were the aerodynamic fundamentals of the design and the results obtained in the flying have shown them to have been soundly chosen.

## Structural Design

The use of a very thin wing, combined with a fuselage almost full of engine, presented many difficult structural problems.

The thin wing (4 per cent) set the major problems and it was decided to use a form of construction in which the spars were perpendicular to the fuselage, with ribs or stringers parallel to the fuselage centre line. This shortened the length of the spars and greatly simplified the joints to the fuselage frames. The wing root bending moment, due to the small thickness, requires a number of spars, situated aft on the wing. Each spar is attached to machined fuselage frames which, to ease manufacture, were made in three pieces and this had the additional advantages of making the frame statically determinate.

The wing consists essentially of two torsion boxes, one at the leading edge and one, the major torsion box, between the chassis and the control surfaces which are cantilevered off the trailing edge of this box. The skins of this aft torsion box are of thick light alloy, the thickness being dictated by requirements of torsional stiffness. Except at the root, the wing skins carry practically all the wing bending loads, but at the side of the fuselage the loads in the skin diffuse out into the three main spars.

The fin is attached at leading and trailing spars in a manner similar to the wing. The main bending attachment was made integral at the root with a cross member, so that once the critical narrow base attachment had been made the introduction of backlash on the fin base through fin removal was rendered less likely, as the detachable attachments were on a wide base. The main fin skin thickness was determined by stiffness requirements for the avoidance of flutter.

The rear fuselage forward to the break joint (seen in Fig. 2) is of monocoque construction and has the petal brakes mounted on it. The problems of mounting the petals have the feature which is reproduced many times on this aircraft, i.e. the difficulty of incorporating into a small space mechanism dealing with large loads.

The centre fuselage consists of heavy frames connected by longeron members; the frames take the wing loads and support the engine.

The cockpit, which droops to provide improved view for landing, provided another difficult problem as almost the entire top of the cockpit has to be open to provide for seat ejection, &c. This problem was dealt with by building the relatively open cockpit on to a complete box forward of the forward bulkhead of the cockpit. The cockpit, when in the up position, is attached to the front fuselage by a conventional set of latch pins.

The control surfaces are constructed with a heavy leading edge torsion box designed by stiffness, and a light trailing edge designed by strength considerations. Provision was made for mass balancing, but this has not been needed.

A point of interest is that the structure weight was 1 per cent less than the weight estimated in 1949.

## Flutter

Very full and careful flutter investigations were made and only a summary can be given here.

Calculations made early in the design stage showed that with the expected impedance of the hydraulic jacks actuating the control surfaces, the addition of mass balance made little difference to the flutter speed of the wing-aileron combination. The results are shown on Fig. 3, the jack impedance being above $1 \times 10^6$ lb-ft/rad.

Later calculations by the Multhopp-Garner theory confirmed this view and showed that the addition of mass balance could bring in a low flutter speed if it caused the control surface natural frequency to be reduced to two-thirds of its value with no mass balance.

In view of these results and the fact that mass balancing would add considerable weight to the aeroplane, it was decided to eliminate it from the aircraft.

This has helped in the avoidance of transonic control surface buzz and single-degree of freedom flutter by keeping the natural frequency of the controls as high as possible. Other favourable factors are the very small trailing edge angle and the large chord of the control surfaces. It has not been found necessary, so far, to fit hydraulic velocity dampers to increase the control surface damping in the transonic region.

Very full flight testing (described in greater detail later) has confirmed this approach, stick tapping having been carried out throughout the full flight range. The responses obtained from stick tapping appear to be sufficiently accurate to confirm the policy of flight vibration testing by this method and, since the taps have been capable of exciting nodes at 35 c/s, it was felt that it was not necessary to use other methods. The use of this method has meant that a large number of records have been obtained in a comparatively short period. The analysis of the results indicates only slight variation of damping with Mach number.

## General Design Considerations

The thin wings and small fuselage, already referred to, provided the over-riding design factors but a further point was kept well to the forefront and that was, so to design the aircraft that easy maintenance and straightforward servicing were provided. This approach has paid high dividends, giving what has been described

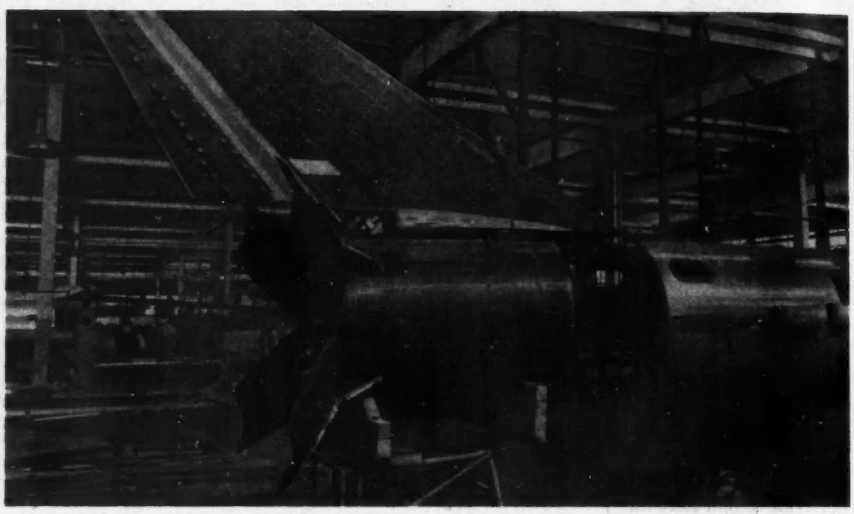

**Fig. 2—Rear fuselage, showing dive brakes extended and fuselage break**

as "airline reliability" and permitting up to six flights per day.

Design matters of interest are :

(1) *The Drooping Nose.*—With the need to keep the height of the windscreen to a minimum and yet give the pilot adequate view at the high angles of incidence at landing, various schemes such as retractable seats, &c., were studied but the final, and the simplest, solution was that of drooping the nose portion containing the pressure cabin. This is hinged on the bottom longerons and is operated by a hydraulic jack. It is a light and straightforward means of giving the pilot better view and has been reliable in operation. It did, however, set up some problems connected with the jettisoning of the hood. To ensure that the hood would jettison correctly, it was desired that it should pivot about an aft hinge on release. This pivot point, however, could not be earthed on to the fuselage, due to the drooping of the nose including the hood. This was overcome by having two "barrow handles" carrying the aft pivot points, tipping with the droop nose and lying flush in troughs in the main fuselage in the nose-up position : these can be seen in Fig. 1. To keep the drag to a minimum, the hood was designed with very small clearance from the pilot's head and is kept flush with the surrounding structure by having hinges on one side, thus avoiding sliding mechanisms which would increase the difficulties of pressure sealing.

(2) *The Main Undercarriage.*—This was a geometric, as well as a mechanical, problem. It was found that levered suspension was the most satisfactory manner of absorbing the required energy with the short length of leg at our disposal and that this would also most easily fit the very limited area and thickness available in the wing housing.

The wheel, when housed, lies in a plane parallel to the inner surface of the upper wing skin. To rotate the wheel into this position the top of the leg is attached by means of a universal joint to an inclined rotating eyebolt, while a side bracing member forms a secondary hinge and controls the path of the wheel during retraction, and a telescopic fore-and-aft member takes the drag. The eyebolt is mounted on a boss on the spar forging.

(3) *General Servicing.*—In line with the policy mentioned earlier this had considerable study and, along the fuselage, a top deck was provided to carry all control rods, electrics, hydraulics, filters, &c., and this has proved invaluable for easy servicing.

(4) *Engine Installation.*—The engine is a Rolls-Royce R.A. series engine with reheat. The basic engine is standard, some small external changes being made to enable it to fit our fuselage.

With the exception of reheat problems in the early stages, there has been little trouble with the power plant, in spite of tight clearances, and the general reliability has been high.

The engine is fitted or removed by breaking down the rear fuselage near the fin and sliding the engine out on rails on to special ground equipment. This has enabled engine changes to be made easily and without breaking any services other than to dive brakes and rudder.

(5) *Hydraulics and Power Controls.*—These have been left to last in the description of the design, although great care and forethought were devoted to them and throughout the whole period of flying they have given every satisfaction.

It was decided in the early days to use power controls of Fairey manufacture, as we were just beginning to manufacture these in quantity and felt that our equipment had many advantages over anything currently available elsewhere. The further decision was taken to duplicate fully the control system and to do without manual reversion. As a result, the aeroplane has fully-powered, fully-duplicated controls, with Fairey valves and "Hydroboosters." To eliminate flutter tendencies as far as possible, the jacks are attached to solid structure and the valves operated by push-pull rods, to keep break-out forces to a minimum.

There are two hydraulic pumps driven by the engine, one of which feeds a main accumulator which powers the flying controls. The second pump feeds a second accumulator which supplies power not only to the flying controls, but also to the main and nose undercarriage retraction mechanism, the droop nose, and the air brakes. In addition to these accumulators, there is an emergency accumulator which can be selected to power either the flying controls or the other services and there is also a brake accumulator.

In the event of an engine or hydraulic pump failure, an emergency air-driven turbine pump feeding the second system can be lowered into the air stream.

The air brakes are also operated by similar methods and the four petals are synchronised to ensure even opening. Another problem here was to operate the petals without excrescences and this was achieved by a system of floating links, giving a good moment arm, but remaining flush when closed.

### Manufacturing Problems

This aircraft was our first attempt at building from solid without any transitional experience of similar types of construction. As a result, many detail problems arose in the manufacture but, by careful jigging and making full use of the solid frames and spares, we consider that the wing profile was made to a measured accuracy of ±0·005in relative to the mathematical form laid down. In addition, the wings are attached to the fuselage by ten close tolerance fixing points and full interchangeability of wing to fuselage was provided.

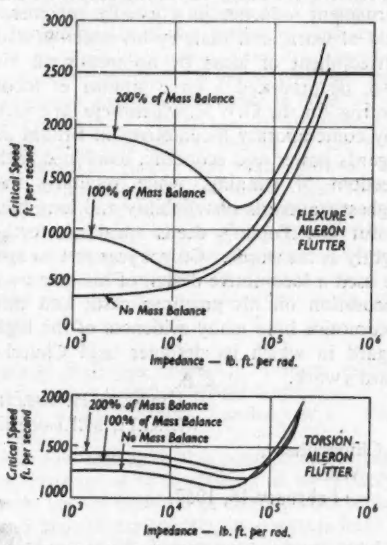


**Fig. 3—Effect of aileron mass balance**

Integral fuel tanks occupy most of the wing and their development was closely studied. It was finally decided to assemble the wing as a dry structure, designed and manufactured to be as fuel tight as possible in this state and subsequently sealed by slushing. This system has worked out very well in practice.

In spite of the major machining problems of the spars and frames from rough forgings, and the assembly difficulties of the thin wings and fin, the aircraft flew about twenty months from the start of construction. It is worth noting that the last three months were mainly involved in inspection, testing of systems, impedance testing and general preflight work, an indication of the complexity of the systems.

Finally, with all these problems behind us, the aircraft made its first flight at Boscombe Down on October 6, 1954.

### Discussion

Mr. F. W. Page agreed with the authors that the 60 deg. delta was an attractive starting point for a supersonic design. On a warplane with a large disposable load, however, the limitations of c.g. travel and the large aft movement of c.p. at the highest speeds became obtrusive. A "notched" planform, imagined as having the elevators and the part of the wing in front of them moved aft to form an all-moving tail, more nearly avoided these problems and gave better damping in pitch : there was not undue difficulty in this solution. He pointed out that many of the stability tests involved trimming the aircraft into a positive *g* manœuvre at supersonic speeds : the restrictions on flight over this country hampered the flying programme seriously, while testing over the sea was excessively risky. Mr. Lickley agreed that a place where supersonic flight could be performed was badly needed : he thought that the problem of where to locate a tail plane was severe.

Mr. R. A. Shaw, remarking that whether there would be any aircraft like the F.D.2 in future was open to question, suggested that the machine would be used to establish a correlation between wind tunnel and free flight observations. He expected that supersonic flying would have to be done in foreign air space.

Wing Commander McDonald inquired whether the designers of the F.D.2 had benefited from the ten years' experience of supersonic flight previously accumulated in the United States. Mr. Lickley said that very little information about this work had been available in this country.

Sir George Edwards drew attention to the statement that little or no priority had been given to this important project. Whatever the reason why the record had not been challenged, the fact that it had stood for nearly a year would offset the unfavourable impression created by the report of a Select Committee.

In answer to a further question, Mr. Twiss related that the automatic observer photographed sixty instruments at intervals of up to two seconds.

Mr. L. W. Rosenthal observed that a "revolutionary" aircraft had been built in twenty-six months : was this because of the two years that lapsed after the contract was placed ? Mr. Lickley explained that it was because the designer's decisions did not alter.

Mr. J. L. Cooper wondered whether sonic "bangs" would be frequent in, say, twenty years' time : Mr. Twiss explained that it was only the early development flying that it was desired to do over land.

Group Captain G. Slade considered that there was enough testing outstanding to occupy the aircraft for two and a half years. He pointed out that only seven pilots had flown either of the machines, and two of them had only five flights between them : there was a pressing need for more such machines to extend the experience of the pilots. For these reasons it was not acceptable that they should be grounded frequently by bad weather : flight testing should be performed in a favourable climate, at least during the English winter.

(At the meeting Mr. Twiss described the flying of the "Delta 2" near Bordeaux in France : he had made high-speed runs along the line of the coast, while the phenomena of sonic "bangs" were recorded on the ground. It was remarked that the technicians involved in these tests lived in the towns over which the aircraft flew at speed : they were, to say the least, tolerated.)

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Institution of Naval Architects.—The spring meeting of the Institution of Naval Architects will be held in the Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, on March 26, 27 and 28, when the following will be the programme. Tuesday morning, March 26, the annual general meeting, followed by paper No. 1, "Iron Ore Carriers," by Mr. James Lenaghan. The annual dinner will be held in the evening at Grosvenor House. Wednesday, March 27; in the morning, paper No. 2, "Ship Hydrodynamic Laboratory," by Dr. J. F. Allan, and paper No. 3, "Effect of Cavitation on the Performance of a Series of 16in Propellers," by Dr. R. W. L. Gawn and Professor L. C. Burrill. In the afternoon, paper No. 4, "Methodical Series Experiments with 0·70 Block Coefficient Forms" : Part I, "The Effect on Resistance and Propulsion of Variations in L.C.B. Positions," by Mr. R. E. Blackwell and Mr. G. J. Goodrich, and Part II : "The Effect on Resistance of Variations in Breadth Draught Ratio and Length Displacement Ratios," by Mr. R. E. Blackwell and Mr. D. J. Doust, and paper No. 5, jointly with the Institute of Marine Engineers, "Further Sea Trials on the 'Lubumbashi,'" by Professor G. Aertssen. Thursday, March 28, in the morning, paper No. 6, "The Interaction between a Ship's Hull and a Long Superstructure," by Dr. J. C. Chapman ; paper No. 7, "Stresses in Deckhouses and Superstructures," by Dr. A. J. Johnson, and paper No. 8, "The Effect of Superstructures on the Longitudinal Strength of Ships," by Dr. J. B. Caldwell, and in the afternoon, paper No. 9, "The Conditions for Unstable Rupturing of a Wide Plate," by Mr. G. M. Boyd, and paper No. 10, "Ship Hull Pressure Measurements," by Dr. N. Hogben. The morning meetings will begin at 10.15 a.m., and the afternoon meetings at 2.30 p.m.

# LETTERS AND LITERATURE

## Letters to the Editor

*(We do not hold ourselves responsible for the opinions of our correspondents.)*

### WELDING AT CALDER HALL

SIR,—Commander Tatton-Brown is quite right in suggesting in his letter of December 28 that the welding on site of 2in thick plate is conservative. Undoubtedly greater thickness could have been welded, but the statement must be taken in its correct context. It is important to appreciate the novelty of the design of the 37ft diameter pressure vessel, involving, as it does :

(1) The internal support of some 1400 tons of graphite and associated equipment.

(2) The supporting structure capable of taking the total load of 1800 tons, with minimum stress values at or adjacent to the connections to the vessel, yet at the same time giving flexibility to cater for thermal expansion.

(3) The large number of openings, particularly in the top head, which is pierced by some 112 branches 12in diameter.

(4) The fact that it was decided to stress relieve the completed vessel. The time for stress relief is dependent upon the maximum thickness, and it is important to keep this time to a minimum in order to prevent possible changes in the grain structure of the material. This was achieved by welding and stress relieving off site all reinforcing plates greater in thickness than the 2in adopted for the vessel.

(5) The fact that the material is subject to nuclear irradiation.

The above items are discussed in the paper on " Design and Construction of the Reactor Vessel," presented to the British Nuclear Energy Conference at the Symposium on Calder Hall on November 22 and 23, 1956.

That the above difficulties were satisfactorily overcome is indicated by the increase in plate thickness to 3in in the designs recently approved for the first nuclear power stations to be built in Britain by private industry.

It is difficult to comment on the appropriateness of the comparison with the 4in and 6in thick pressure vessels of the U.S. Navy Department without knowing their size and application or the site conditions obtaining during their fabrication.

GORDON BROWN, D.C.E.,
(Civil Reactors)

United Kingdom Atomic
Energy Authority,
Risley, Lancashire,
February 12, 1957.

### GEORGE JACKSON CHURCHWARD

SIR,—Dr. Tuplin's provocative dialectics have often been a source of enjoyment and enlightenment to me in the past, but I cannot think that this occasion—the celebration of the centenary of the birth of a great engineer—is in the least proper for the display of that talent.

Your leader described Churchward's virtues very fairly ; there was clearly no intention on your part to provide a balanced criticism of his work. Nevertheless, it is worth saying that while every human being—scientist, engineer or even composer of music—must use the past and the present as the foundation for such originality as he may possess, yet it is the selective and heuristic skill displayed that defines his status and merits.

Every engineer—locomotive or otherwise—worth his salt takes note of current practice all over the world in his line, and uses so much of it as he considers of value to him. The reason why Churchward is almost universally regarded as the greatest of British locomotive engineers is that he really does seem to have settled on the right answers to all the major problems of locomotive design right down to the present day, producing a permanent influence in a usually ephemeral field of work, and that, by his selection and development of ideas by no means all his own, he produced a large number of locomotives for the G.W.R. which were far above any contemporary locomotives in Britain as regards power and economy, combined with freedom of running, while retaining the highest standards of reliability and long life.

But Dr. Tuplin's deeds speak as forthrightly as his words. Only a year or two ago he used a locomotive design of his own as a decoration on his greetings card, and this locomotive bore many evidences of the high regard in which its designer held Churchward's work.

KENNETH H. LEECH,
M.I.C.E., M.I.Loco.E.

Chippenham,
Wilts,
February 16, 1957.

### TRACTION ENGINE RAILWAY LOCOMOTIVES

SIR,—I very much appreciated Mr. Abbott's excellent account of traction engine type railway locomotives. I notice that he confirms my idea that " Rattlesnake " was probably the first of the type. I, myself, have rather doubted, however, whether she was really, as the late A. R. Bennett states, " designed and built by Mr. Boulton." In Bourne's *Recent Improvements in the Steam Engine*, published in 1869, there is a picture of a traction engine by Clayton and Shuttleworth, which has an extraordinary resemblance in many ways to " Rattlesnake." It is a double-cylinder engine with the cylinders in the smokebox, a dome over the firebox and a chain sprocket on the crankshaft. The safety valve, regulator, reversing lever, design of crankshaft saddle, &c., all seem remarkably similar. Unfortunately, it is not possible to see if the back plate is flanged outward. Boulton's engine No. 17, said also to have been built by him, has a similar boiler to " Rattlesnake," but surmounted by a saddle tank with a geared engine underneath, and I always felt both engines were reconstructed from Clayton tractions bought by Boulton. As Mr. Abbott says, the outward flanged back end is very unusual in this country, but it was very popular in the U.S.A. and Canada. In the case of some " rear-mounted " American engines, the lower part of the firebox wrapper was extended behind the back end to carry the driving axle. The drawing of " Rattlesnake " in the *Chronicles* shows some signs of the firebox side sheets having once extended back in this fashion, possibly to support the back axle.

I was interested to hear of the " Convertible Steam Sappers " of the 'seventies, as I remember in 1914, when training as a sapper and driving an 8 h.p. Burrell, I met an elderly time-expired R.E. man who spoke in enthusiastic terms of these " convertible " Aveling engines which he had driven on both road and rail. The only surviving locomotive of this type I know is the " Sirapite " at Leiston. I saw her in steam about eighteen months ago and hope she is still at work, as she was then well maintained. She has a very prominent flywheel brake. Were these brakes common on these engines ? These were very powerful brakes as they operated on the fast-moving flywheel rim, but I believe that unless used with discretion they were very hard on the crankshaft through which the braking torque was transmitted.

GEOFFREY K. KING, A.M.I.C.E.,
A.M.I.Mech.E., A.M.I.E.I.

Norwich,
February 15, 1957.

## Literature

**Friction and Lubrication.** By F. P. BOWDEN and D. TABOR. Methuen and Co., Ltd., 36, Essex Street, London, W.C.2. Price 10s. 6d.

FRICTION is so much the concern of the engineer that it is a matter of surprise that the serious study of its fundamental nature should be of comparatively recent origin. Such study may be said to have had its origin in 1918 when, as one of the first acts following its formation, the Department of Scientific and Industrial Research set up its Lubricants and Lubrication Committee. The work which this committee started at the National Physical Laboratory, first under Stanton, and continued by such men as Jakeman, Clayton and Fogg, is well known to our readers. Although fundamental in outlook, the value of this work has been mainly to show how lubricants function in bearings and gears, rather than to elucidate the nature of friction itself. Sir William Hardy, who became chairman of the D.S.I.R. committee in 1920, was, on the other hand, more concerned with such factors as the effect of chain length of a lubricant molecule on its friction reducing propensities. The full flowering of the tradition established at Cambridge by Hardy is represented by the achievement of the authors of this book, who have built up, step by step over the last twenty years, a comprehensive view of the nature of friction and lubrication which must be taken into account by all workers in the field. The present book sets out this view without mathematics and with that simplicity of approach which is characteristic of the authors.

The essence of the authors' theory is that, when even the smoothest of surfaces are placed together, contact occurs only at the tips of asperities. The load, being concentrated at a few small points, high local stress occurs and the material yields plastically, causing load to be distributed. It is thus shared between more asperities until a balance is achieved between applied load and the plastic yield stress of the material multiplied

by true area of contact. It has been shown by electrical contact resistance and other methods that the true area of contact is proportional to the applied load. (Other workers, notably Hirst, have contended that this result could also come about by elastic rather than plastic deformation.) Over the regions where intimate contact occurs, strong adhesion takes place (cold welding) and the material of the two surfaces becomes a continuous solid. When the surfaces slide over one another the junctions so formed must be ruptured and the force required to do this, the authors contend, is the force of friction. Because both the area of the junctions will be related to the load by the properties of the materials, which will also govern their transverse strength, as more load is applied, so will greater transverse force be required to cause movement. Thus, coefficient of friction is usually independent of load.

When a junction is ruptured during sliding, the authors consider that it may do so in one of four ways. When the junction is weaker than both metals it will shear at the interface. When the junction is stronger than one of the metals the cleavage will occur a little distance within the weaker metal; this will not greatly affect the friction but considerable wear will occur. If the junction is stronger than both metals the cleavage will occur within both metals, but more frequently within the weaker metal. When similar metals rub together the junctions will be of the same material as both surfaces, but will become work hardened by the process of deformation; thus rupture will occur within the bulk of the materials and wear will be very heavy. The foregoing is based on the assumption that clean metal comes into contact with clean metal. It is fortunate that, in practice, metals are covered with oxide films which serve to restrict the extent of the junctions formed and to facilitate their rupture. Experiments of the authors on very clean metal in vacuum are described. In experiments on outgassed iron, seizure of one metal to the other occurs, but as soon as oxygen is admitted, friction falls so as to give a coefficient of friction of 2 and, after an interval of fifteen hours, it falls to the normally quoted figure of 0·5. Naturally, the oxides of different metals possess different mechanical properties which will affect frictional behaviour. Hardness and frictional properties of the oxides of a few common metals are given in a table. It may be commented that this is one of the sections of the book which might well have been expanded. The reader might expect to learn how such metals as stainless steel and titanium behave, and how the different oxides of iron affect frictional behaviour. It is part of the authors' thesis that, because true contact is concentrated over a minute area, the frictional energy will first be concentrated in a very small quantity of matter so that high local temperatures result. Temperature will be limited only by the melting point of the materials. Where non-conducting materials are involved temperatures as high as 500 deg. Cent. may be attained at a speed of a few feet per second. The important point is made that, if the material oxidises, additional heat is evolved, the local hot spot perhaps reaching a temperature of 2000 deg. Cent. The warning is given that such local hot spots may initiate explosions although the temperature rise of the bulk of the rubbing materials may be negligible.

Lubrication, the act of deliberately separating the two rubbing surfaces by a third substance, is divided into two categories: hydrodynamic and boundary lubrication. The former, the situation wherein sufficient pressure is generated within a fluid to separate the surfaces completely, is dealt with somewhat superficially. The treatment is sufficient, however, to allow boundary lubrication to be treated in true perspective and adequate references for further study are given, although there no notice is taken of three books, by R. R. Slaymaker, D. D. Fuller, and F. T. Barwell, respectively, no doubt issued after this book went to press.

Hardy's view that boundary lubricants were effective because they were physically absorbed onto the surfaces is contrasted with the authors' own view that the fatty acids, for example, react with the material of the surfaces to form soaps. Evidence is adduced to show that these soaps are the effective lubricants. The book concludes with an account of extreme pressure lubrication.

Paradoxically, the only criticism that can be made of this book is that it is so well written as to make an extremely difficult subject appear to be simpler than it really is. The behaviour of the materials used in the diverse conditions encountered in engines and gears, for example, is more complex than this book suggests, and there is little factual information of direct use to the practising engineer. The light it throws on the basic processes of friction and wear, however, will be of very great indirect benefit. The book is well produced and illustrated and fits easily in the pocket. In spite of its academic basis, we recommend the busy engineer to carry it in his pocket, so that by dipping into it at odd moments he may combine profit with pleasure.

**World Railways, 1956-57.** Fourth edition. Sampson Low's "World Railways," Ltd., 25, Gilbert Street, London, W.1. Price 84s.

THE new edition of this comprehensive work on railways is as interesting as its predecessors, and in addition to having been revised and brought up-to-date, its contents have to some extent been rearranged. An interesting addition is the inclusion of a tabular summary listing the leading details on the railways at the beginning of each of the sections covering the different continents. In these summaries thirty-two headings cover such details as gauge, track length, rolling stock, freight movement and track particulars, and some 1470 railways have been tabulated in this way for quick and easy reference.

The section dealing with railways is well-illustrated with maps, diagrams and photographs and gives a useful picture of rail transport throughout the world. In this section each continent is dealt with separately with the respective countries arranged in alphabetical order. Nearly 160 major railway systems are covered individually as well as in the tabulated summaries. To show the general trend of development on these railways, notes are now given of alterations and improvements during the past year or so, together with work in hand and what is proposed for the future. Of particular interest are the details given of the railways of the U.S.S.R. and a short note on those in China, which are based upon official information received from those countries. These notes are considered to give a good account of the past and present activities of the two countries and an indication of the very extensive programmes of future development.

The rapidly growing interest in electrification in practically all parts of the world is noticeable throughout the new edition of the book. As in most other countries, electrification forms an important part of the railway programme in the U.S.S.R. and it is stated that the 1956–60 plan envisages the electrification of over 5000 miles of lines, whilst plans are being made to electrify up to 25,000 miles of line in the next fifteen years. In that country the 3000V d.c. system is in use on all main lines and most of the recent suburban electrified lines; it is stated that, following the use of 20,000V, single phase, 50 cycles a.c. on an experimental section, plans are in hand to extend this system. Excluding the U.S.S.R., the combined total route length of electrified lines in Europe is stated to be some 22,500 miles and during the next ten years it is probable that about 6000 further miles of route will be electrified.

The steady replacement of steam traction by diesel power is shown in most countries in Europe, where the general tendency now appears to be the introduction of electric main line traction on many routes, with diesel locomotives and rail cars on the remaining lines. This steady decrease in the use of steam is indicated in practically every country in the world, with the particular exception of India and South Africa, where coal is cheap, but even in these two countries diesel locomotives are now in service.

As in the last edition of this book, a section is devoted to the products of locomotive and rolling stock builders in all parts of the world, and the section on diesel engines for rail traction is again included. Four surveys of topical interest included in the volume deal with "Radio in Railway Service," "Long Welded Rails and Rail Fastenings," "Lightweight Trains" and "Track Maintenance Machinery."

Once again the publishers have successfully concentrated in a single volume a vast amount of interesting information. Previous editions have already made the book a valuable standard work of reference for those concerned with all aspects of railway operation and administration, and the new volume will be welcomed as an up-to-date source of information not otherwise readily obtainable.

**Defects and Failures of Metals: Their Origin and Elimination.** By E. P. POLUSHKIN. Cleaver-Hume Press, Ltd., 31, Wright's Lane, London, W.8. Price 72s.

THE title of this book gives promise of its being exactly what many inspectors of engineering materials have been looking for, and it may be said, with some qualifications, that this promise is largely fulfilled. The book is designed to survey the origin and methods of elimination of failures and defects over the whole field of metals and alloys. After a general introduction on the interpretation of evidence, there follow chapters on segregation, blowholes and porosity in metals, pipe, impurities in metals, decarburisation of steel, scaling, harmful effects of residual stresses, fatigue of metals, flakes, failures in heat-treatment, the embrittlement of metals, the origin of cracks, defects in shape, surface and size, wear of metals and corrosion. Each chapter is divided into from three to six sections, comprising:—definition and general characteristics of the defect; origin, causes and contributing factors; means of identification, methods of testing; occurrence, location of defect or susceptibility to it; detrimental effects; prevention, correction and elimination. Every chapter is illustrated by a number of excellent photographs and photomicrographs representing the defects and failures described. The classified list of references at the end of each chapter is very valuable. In some fields it is exhaustive; in others it forms an essential nucleus upon

which specialists in any particular metal may probably build up a more complete bibliography in their own field of interest.

The author has chosen to examine together in the same chapter similar defects occurring in different metals and arising from different causes. The defects in iron and steel are usually so different in character from those occurring in non-ferrous metals that separate treatment would not only have been justifiable and convenient to the reader, but is, in fact, unavoidable, as is shown by the chapters on flakes and on decarburisation. Even in the chapter on segregation the greater part of the text refers to steel, and references to the non-ferrous metals and alloys occupy very little of the space. Inverse segregation is mentioned only in connection with steel in which the phenomenon is entirely different in cause and effect from that to which the term is generally applied in connection with non-ferrous alloys. The non-ferrous metals seem, in fact, to have suffered by the arrangement adopted : there appears to be no reference to the " gassing " of copper, the extrusion defect, dimensional changes and cracking in zinc alloys, or any defects occurring in nickel alloys. Many readers would have preferred a more definite separation of the discussion of steel and non-ferrous metals with adequate cross reference to features in common (such, for example, as certain ingot defects), and advanced students, who will be called upon to deal with the manufacture of some of these metals in the future, would be likely to get a more balanced picture of the influence and incidence of the defects if they had been dealt with in relation to separate metals or groups of metals.

The author mentions, and might insist more strongly, that in assessing the importance of defects or the causes of failure an exact knowledge of actual conditions of service is essential. Segregation or inclusions are said on page 1 to be always harmful, but later it is indicated that they are unobjectionable under correct conditions of use when deliberately employed to give free machining. There is generally no need for undue concern about the normal amount of inclusions in steel. Failures of steel due to inclusions are extremely rare. On the other hand, at least half the failures which occur are to be attributed to unsuitable conditions of service. The inexperienced may too hastily conclude, on the strength of a few micros, that a particular failure was primarily due to inclusions or to a poor structural condition of the metal. The author rightly insists upon the importance of visual and macrographic examination, without which the evidence of microstructure may be quite misleading. A failure can rarely be attributed to a single factor and therefore a metallurgist without a sound knowledge of the technique of production and of the conditions of service of a component that has failed is at a serious disadvantage in assessing the cause of failure and the action required to remedy a defect.

The author's comment emphasising the importance of collecting and preserving specimens of faulty material may be heartily endorsed. Apart from the interest of such a collection for instructional purposes and comparison with future examples, the examination of defective material is often the starting point of important lines of research, and the knowledge gained from failures is often the basis of improved technique and sounder design.

The book is unique in conception and has been compiled with meticulous care. It can be recommended as an excellent account of common defects which may contribute to the failure of metals and alloys in service.

**Modern Mathematics for the Engineer.** Edited by EDWIN F. BECKENBACH. McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 56s. 6d.

WITH every allowance for the fact that the word " engineer " has a very wide range of meanings, the title of this book is misleading. All but five of its nineteen sections are almost entirely mathematical in character, and although that does not preclude an engineer from reading them, he will find little in them to show him exactly how to apply the methods discussed to practical problems. The section by Professor John W. Green on " Exterior Ballistics " can be read with interest by an engineer with modest mathematical training, and the section by George E. Forsythe on the nature of relaxation methods could be useful to an engineer with academic leanings, but the rest of the book is for mathematicians. It records the substance of a series of lectures conducted by the University of California, the authors including twelve Professors of Mathematics, a Research Mathematician, a mathematician in industry, three Professors of Engineering, a Chief Scientist (U.S. Navy), and a Research Chemist.

Each section represents a lecture on a mathematical subject with which the reader must already have some acquaintance. The book constitutes a survey, for mathematicians rather than engineers, of certain kinds of mathematical problem that may be the approximate expressions of physical problems with possible associations in engineering. It could be useful to a mathematician who is intending to offer his services as a solver of special problems that may arise in the more academic branches of engineering. It seems unlikely in itself to convince an engineer that the methods it discusses could be directly useful to him. On page 149 Professor Sokolnikoff writes : " The engineer seldom derives comfort when the mathematician says that he has solved the problem because his assumption that the solution does not exist has led him to a logical contradiction." Most of the book will give an engineer just this feeling of absence of comfort. A mathematician may find it good reading and may approve the confinement of numerical examples to half a dozen pages, but an average engineer is likely to find most of it unrewarding.

## Technical Reports

*Etude Expérimentale de la Convection Forcée sur Paroi Mobile (Hyperconvection Favre).* By Charles Bory. Publications Scientifiques et Techniques du Ministère de l'Air, No. 312. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price 1000 francs.—The idea of using a moving endless ribbon for the study of forced convection is due to A. Favre, who, in a paper,* has indicated this possibility of increasing the heat transfer. The studies which he made of the flow over obstacles, the surface of which was moving in the direction of the flow, showed that the boundary layer could be made to disappear so that the flow of a real fluid resembled that of a perfect fluid. Since a quasi-stagnant layer has a low thermal conductivity, its suppression would be expected to increase the amount of heat transmitted. Conversely, it might seem strange that by eliminating relative movement between the surface and the adjacent fluid, and so reducing the situation to one of pure conduction, an increase in heat transfer should be obtained. The explanation lies in the fact that the surrounding fluid is constantly replaced in the case of cooling by fresh cold fluid, so that the temperature gradient at the surface is steeper than it would be if the surface were stationary. A more advanced theory is given in the second part of the present work, which takes into account the partial stagnation of the fluid during approach, and the effects of turbulence. The study concludes with a discussion of possible practical applications.

*Colloque de Mécanique, Poitiers, 1950.

*Utilisation des Compteurs de Geiger-Müller à L'étude de Variations de Texture de Laminage Suivant la Temperature de Déformation.* By François Provost. Publications Scientifiques et Techniques du Ministère de l'Air, No. 313. Service de Documentation et d'Information Technique de l'Aéronautique, Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price 800 francs.—Applying the technique of the Geiger counter, a method is developed for investigating the changes in structure during hot-rolling and the influence of the rolling temperature.

Operating conditions and accuracy of measurements of X-ray diffraction of metallic specimens are discussed, and a description is given of a set-up, based upon these considerations, for exploring the Debye-Scherrer rings.

Test results were obtained for the hot-rolling of aluminium sheet, which was heated between passes to temperatures varying between room temperature and 400 deg. Cent. It was found that there was little effect upon textures for temperatures below 350 deg. Cent. Above that temperature, a new texture is formed which, however, soon disappears owing to recrystallisation. Micrographic studies show that this recrystallisation, which takes place during the deformation, gives rise to a much coarser grain than if the metal were first deformed cold and then heated. Some special effects of recrystallisation were noted.

*Determination of Moisture in Solids.* By P. J. Geary, B.Sc. (Eng.). British Scientific Instrument Research Association, Southill, Elmstead Woods, Chislehurst, Kent. Price 7s. 6d.—This publication surveys known methods of determining the moisture content of solid materials and lists instruments and other apparatus for making measurements of moisture content which can be obtained in Great Britain. Information widely distributed in literature, dealing with different materials and in scientific literature generally, has been assembled in this one handbook. There is an introduction dealing with general points concerning the retention of moisture by solids and the determination of moisture content ; a list of reviews and bibliographies on methods of measuring moisture content ; a table of methods ; brief descriptions of the forty-odd techniques surveyed ; selected references examining or exemplifying each technique ; and particulars of any instruments or other apparatus available commercially in Great Britain for determining moisture content by each technique, with names and addresses of manufacturers or agents.

*Vibration Analysis Tables.* By R. E. D. Bishop and D. C. Johnson. Cambridge University Press, Bentley House, 200, Euston Road, London, N.W.1. Price 10s. 6d.—There are two ways of using the information that is contained in this book. First of all, the results which are listed for beams, shafts, and so on, are of immediate use in vibration analysis of those systems. Amongst the data given are " receptances " —that is to say, the measures of the readiness of the various systems to respond to harmonic excitations. These functions are themselves of importance in the analysis of lightly damped systems which are not excited at near-resonant conditions ; they also form the basis of the second way of using this book. For the results may be used in connection with compound systems of which a system dealt with here forms part. This is because the frequency equation, the principal modes and the receptances of a system can be deduced when the receptances of its simpler parts are known. Lists of notation provide sufficient information to explain the entries.

## Books Received

*The Theory of Vibrations for Engineers,* Third edition. By E. B. Cole. Crosby Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W.7. Price 30s.

*Thermodynamic Tables and Other Data.* Edited by R. W. Haywood. Cambridge University Press, Bently House, 200, Euston Road, London, N.W.1. Price 2s. 6d.

*A Practical Guide to the Design of Grey Iron Castings for Engineering Purposes.* Council of Ironfoundry Associations, 14, Pall Mall, London, S.W.1. Price 12s. 6d.

*Heating and Air Conditioning of Buildings.* Third edition. By Oscar Faber and J. R. Kell. The Architectural Press, 9–13, Queen Anne's Gate, Westminster, London, S.W.1. Price 65s.

*National Coal Board : The First Ten Years.* Edited by Sir Guy Nott-Bower and R. H. Walkerdine. The Colliery Guardian Company, Ltd., 30-31, Furnival Street, London, E.C.4. Price 21s.

# Sponsorship Schemes in Remploy Factories

A LITTLE over a year ago, Remploy, Ltd., announced its industrial "sponsorship" scheme, and the first of the organisation's works to operate this scheme is now in production. The scheme was introduced with the twofold object of assisting firms which desire to expand, but are experiencing a shortage of labour or space, and of providing employment for larger numbers of disabled or handicapped men and women who are otherwise unable to obtain jobs in industry. Hitherto, the ninety factories of Remploy, Ltd., have concentrated on productive work competitive with normal industry, the additional costs involved as a result of providing special facilities for employing badly disabled people being met by a subsidy from the Government. At this point, it is interesting to note that the annual subsidy of nearly £2,500,000 when spread over the 6000 employees of the organisation, means that each costs the country a little over £400 a year. Against this sum there must be set the taxes paid back to the Exchequer by the employees, and it must also be taken into account that they would otherwise be in receipt of unemployment benefit or national assistance in some form. Taking all factors into account it is stated that the net cost to the country of each employee is in the region of £200 a year, which cannot be considered excessive when it does so much.

With the sponsorship scheme it is hoped that, given sufficient backing, the annual rate of subsidy will be reduced whilst meeting a need of industry. Under the scheme a sponsoring firm undertakes to equip a Remploy factory with plant for manufacturing the product required and to provide the technical knowledge. Thereafter, the firm supplies the raw material and buys back the finished products at an agreed economic price. The nature of Remploy establishments naturally makes it necessary for the sponsoring firm to guarantee a continuity of orders over a long period, as changes in methods cannot readily be made with the class of labour involved.

The scheme can thus be used to provide a solution to the space and labour problem for a firm which wishes to expand, but has not the facilities. Where such a firm has a section engaged on the continuous production of a component used in large numbers and in constant demand, the sponsorship scheme can be used to good effect. By removing this section, complete with its equipment, to a Remploy factory, the space and labour previously involved can be fr ed for new production. The scheme can also be used to advantage by a company wishing to reorganise its production lines and methods, whilst it also requires to retain older plant in service for the supply of components and spares.

The first sponsorship scheme connected with the engineering industry began in January last year, when Dowty Seals, Ltd., of Cheltenham, equipped a Remploy factory at Bristol for the production of synthetic rubber "O" rings and bonded seals in which a rubber sealing insert is bonded in the bore of a metal ring. This factory was previously engaged in woodworking for the furniture trade, and it now has a production staff of fifty-six men and women who are handicapped as a result of tuberculosis. With this staff the factory is now producing each day some 22,000 "O" rings in twenty-five sizes, and 12,000 bonded rings in six sizes, and in two grades of rubber.

The whole of the plant and tooling was installed by engineers from Dowty Seals, Ltd., who also undertook to train a nucleus of staff for the various processes. The main production floor covers an area of some 8000 square feet, and a further area of 5000 square feet is available for expansion if demand warrants it. The equipment installed includes three main injection moulding stations, two of which can be seen in our illustrations on this page. These two stations are used for "O" ring production and a third station, part of which can be seen on the left of the injection moulding section, is engaged in making the bonded seals. Each station has two injection moulding rigs, a curing oven and a mould stripping and preparation bench.

In the production cycle the moulds, after injection, are transferred to a tunnel curing oven from which, at the end of the prescribed curing period, they are ejected into a chute leading to the stripping bench. When the moulds have cooled they are stripped and the rubber rings removed, the mould parts then being passed on to an adjoining section, where they are cleaned and reassembled for transfer back to the injection machine.

The "O" rings have a majority of the moulding flash removed in a barrelling operation, before they are taken to the finishing lines, to be seen in our second illustration. Here the slight rounded ridge of flash on the inside and outside of the rings is removed using simple driving equipment and abrasive blocks. Finally, every ring is inspected to A.I.D. requirements before it is released to a packing and dispatch section.

The bonded rings follow a similar manufacturing practice, except that the metal rings are degreased and coated internally with an adhesive to give the required bond between the rubber and the metal. This cleaning and application of adhesive is carried out in separate rooms to ensure controlled dust-free conditions in preparation. After moulding, the flash on these rings is removed by a punching operation on a special rig, and the cleared rings fall from the rig on to a moving inspection belt for final checking before dispatch.

It will be appreciated that this particular class of production, which involves only a small amount of physical exertion, but accuracy in finishing and careful inspection, is well suited to the type of labour employed. From the outset, no concession has been given in the quality or accuracy of the rings produced, which have to be fully up to the standards required in the parent works. We are informed that these standards have been maintained and a satisfactory output attained in the relatively short time the factory has been in full production. Following the successful results obtained at this establishment, Dowty Equipment, Ltd., has now started a second sponsorship scheme in a Remploy factory at Sheffield. At this factory work has started on a repair and maintenance programme for the Dowty pit props used by the National Coal Board. Special plant is being introduced to enable physically handicapped workers to dismantle, clean and rebuild pit props with overhauled or new parts. At first sight this would seem to be work outside the normal scope of a physically handicapped person, but we understand that initial results are encouraging and may lead to further similar centres being set up in other mining areas.

Remploy, Ltd., states that other sponsorship schemes of this nature are at present being studied, but further inquiries from industry would be welcomed, particularly if they concerned forms of production similar to the one we have described at the Bristol establishment.

**(Left) Injection moulding equipment for the production of synthetic rubber "O" rings and bonded seals. (Right) Finishing and inspection lines for sealing rings**

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ELECTRICAL ENGINEERING AND ALUMINIUM.—A Symposium on Aluminium in Electrical Engineering has been arranged by the Aluminium Development Association and will be held on Thursday and Friday, May 16 and 17, at the Institution of Electrical Engineers, Savoy Place, London, W.C.2. There will be three sessions entitled: "General and Economic Considerations in Using Aluminium in Electrical Engineering," "Aluminium in Transmission and Distribution Lines" and "Aluminium in Electrical Equipment," at which twelve papers will be presented. The principal objects of the symposium will be to present authoritative information on experience gained and to indicate future potentialities for wide and full discussion by electrical engineers, together with the aluminium industry. Papers will be sent in advance to those registering for attendance and requests for invitations to attend, which are open to electrical engineers and others with experience in the electrical industry, should be addressed to The Aluminium Development Association, 33, Grosvenor Street, London, W.1.

## Submersible Drainage Pump

A NEW heavy-duty, electrically-driven, submersible drainage pump developed by Sumo Pumps, Ltd., was recently demonstrated at the firm's works at Crawley, Sussex. This pump is designed to handle water containing mud, sand and small solids which can pass through a ¾in square mesh strainer. It is driven at 3000 r.p.m. by a 7 nominal h.p. motor on the lower end of the shaft of which the impeller is mounted. Two sizes of impellers are available—one having a capacity of from 5000 g.p.h. at 50ft head to 15,000 g.p.h. at 17ft head ; and the other 6000 g.p.h. at 60ft head to 15,000 g.p.h. at 30ft head. The impellers are quickly and easily interchangeable when it is required to vary the performance of the pump.

One of the new pumps can be seen in the accompanying illustration, and it will be appreciated that the pump can either be suspended by its rising main or by ropes, or allowed to stand

**Submersible drainage pump capable of handling water containing solids up to ¾in in size**

on its base at the bottom of a borehole. A single stage bronze impeller is mounted on the stainless steel shaft below the motor and has a replaceable wearing ring surrounding its inlet. The interior of the squirrel-cage motor is filled with a light oil which lubricates the lower journal bearing ; and the upper bearing, which also takes the thrust load, is enclosed in a grease-filled chamber. The stator windings are sealed by the outer walls of the motor housing and a thin stainless steel enclosure tube.

The water inlet chamber at the base of the pump is surrounded by a mesh strainer, and water leaving the impeller flows up through co-axial passages surrounding a large area of the motor housing walls. This flow of water provides adequate cooling of the stator whilst the pump is running, and the design is such that if the water supply ceases the pump can run on snore for an appreciable time. An automatically re-setting thermostat built into the stator housing protects the motor against overheating, by switching it off if the pump is left running dry for too long or if it jams accidentally. Starter equipment developed for the pump is designed for open site installation and is fully protected against unskilled operation.

The pump weighs only 238 lb and it can be readily carried by two men or rolled along by one man. Particular attention was given in design to ensure ease of handling on site, and to provide adequate strength for relatively rough usage in transport without call for special protective packing.

## Internal Measuring Machine

AN internal measuring machine, which is now being made by the Coventry Gauge and Tool Company, Ltd., Coventry, is stated to be capable of measuring the diameters of finely ground or lapped bores to an accuracy of ±0·000 01in or less. This machine is basically a comparator using high-precision slip gauges as reference standards. It is designed to measure internal diameters from 0·1in to 3in and diametral measurements can be made to the above stated accuracy down to a bore depth of 1in. By reversing the component end for end on the worktable the depth can be doubled. It is pointed out that actually bore depths down to 3in can be measured, but when using this extended range the measurements have to be made at lower magnifications and there is a corresponding drop in accuracy.

The machine is constructed to a design developed at the National Physical Laboratory, and a description we have received from the maker is based upon extracts from a paper by Mr. C. O. Taylerson and Mr. A. Turner, entitled "A New Precision Measuring Machine," presented at a symposium on engineering dimensional metrology. The machine can be seen in the accompanying illustration ; it has a rigid cast iron body which supports an elevating worktable, and an adjustable slide on its column carries an autocollimator and measuring head assembly. This slide has a longitudinal motion parallel to the axis of measurement through one handwheel, and a transverse movement through a second handwheel.

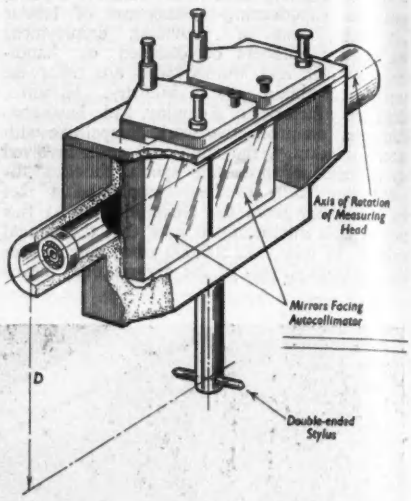
The reference standard and the work to be measured are placed, in turn, on the worktable, which can be raised or lowered through a range of 6in by a handwheel, and locked by a clamp. The upper surface of the worktable can be rotated by hand through 360 deg., and a fine rotational adjustment over a limited range can be applied to it at any position by a handwheel. This fine adjustment is required when lining up the end faces of the reference standard, so as to bring them square with the measuring axis of the machine. Concentric circles scribed on the surface of the worktable provide an approximate guide for placing the standard and the work symmetrically in position, and quick-action friction clamps are provided for securing them in place. The edge of the worktable is graduated at 5 deg. intervals as a guide to the orientation of the measurements made. A stem graduated at 0·05in intervals, which is attached to the worktable, indicates the axial depths of the diametral measurements made in the bore.

The measuring head assembly incorporates a pair of optical reflecting mirrors mounted on a vertical arm to which is attached a double-ended stylus which enters and contacts the bore

**Internal measuring machine designed to measure bores to an accuracy of 0·000 01in**

under measurement. The length of the stylus fitted is within about 0·05in of the bore diameter to be measured. This assembly pivots on precision ball bearings in a pair of supporting arms integral with the main slide. The double-ended stylus can be biased to contact with each of its ends in turn the diameter being measured, by rotation of a handwheel on the slide. The operative working load applied to this bias is less than 1 oz.

The drawing of the measuring head we reproduce shows the two optical mirrors which face the autocollimator and return to it images of its cross wire. In order that these images may




**Diagrammatic arrangement of measuring head assembly**

be initially directed into the autocollimator range, each mirror can be tilted in the vertical and horizontal planes by rotating the knurled headed screws. The centres of these mirrors lie approximately on the axis of rotation of the measuring head. When correctly adjusted, each mirror respectively reflects the image of the autocollimator cross wires into the eyepiece when the appropriate end of the stylus is contacting the bore of the work.

A Watts micropic autocollimator is fitted on the machine slide, and one main division on the measuring drum of this instrument corresponds to an angular displacement of the mirrors of one second of arc. The distance *D* between the axis of rotation of the measuring head and the axis of the doubled-ended stylus point is made equal to 2·062in ; thus an angular displacement of the measuring head of one second of arc will cause the measuring contacts of the stylus to travel through a length of arc equal to 0·000 01in. One second of arc is subtended by 0·000 004 85in at a radius of 1in. As autocollimator settings on the instrument can be repeated within 0·2 to 0·3 seconds of arc when receiving reflected images from mirrors of first-class quality, it will be appreciated that the location of either the left-hand or right-hand contact of the double-ended stylus, whichever happens to be in action, can be determined to well within 0·000 005in.

The reference standard for the machine is of box form and is built up so that the internal dimension of the box is within about ±0·0005in of the size of the bore under measurement. It comprises two lapped steel end pieces which are separated the appropriate distance by two combinations of slip gauges of equal length. Experience has shown that this size can be relied on within 0·000 01in, provided that slip gauge combinations of equal length are selected and that care is exercised in wringing the individual parts together.

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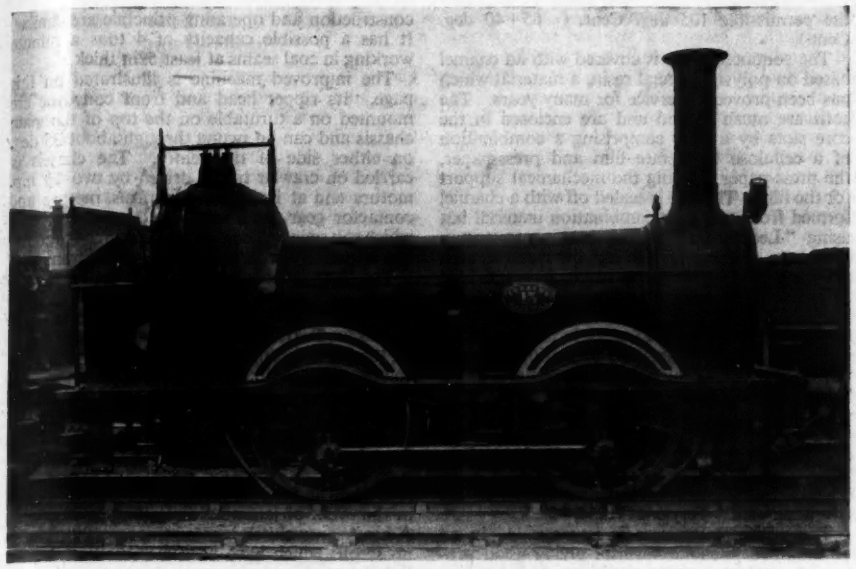
AGRICULTURAL AIRCRAFT.—An unrestricted certificate of airworthiness has now been granted to the Edgar Percival E.P.9. Sixteen aircraft have already been completed and can be supplied with float or ski undercarriages. One is in service with the Manawatu Aerial Top-Dressing Company of New Zealand, carrying 2000 lb of fertilizer on each trip. The machine was briefly described in these columns on September 14, 1956, page 386.



Fairbairn locomotive delivered to Furness Railway in 1858. The peculiar position of [the cylinders was characteristic of Fairbairn designs

## Some Fairbairn Locomotives

By E. C. POULTNEY, O.B.E.

THE presentation of a portrait of the first Sir William Fairbairn to the Institution of Mechanical Engineers, recorded in THE ENGINEER for December 21 last, not only recalls a distinguished engineer of diversified attainments, but also the early history of the locomotive and, in particular, the part played by a notable, though comparatively short-lived, firm of builders, William Fairbairn and Sons, Manchester. The writer has recollections of locomotives constructed by this one-time well-known firm supplied to the Furness Railway, some of which, though first put into traffic as long ago as 1854, were still at work shunting at the Barrow Docks during the early years of the present century, having thus completed some forty-five years of hard work without, so far as can now be remembered, any major renewals. At one time there were eight of these Fairbairn engines in service, delivered in the following order. The first engines of 1854 were Furness numbers 7 and 8, followed, in 1855, by two more, numbered 9 and 10. Four more were put into service in 1858 and 1861, numbered 13 and 14 in the former year and 15 and 16 in the latter. All the engines were of Fairbairn's standard design and in several respects were a copy of Edward Bury's engines and similar to other Furness engines previously supplied by Bury, Curtis and Kennedy of Liverpool.

The photograph of engine No. 13, one of those delivered to the Furness line in 1858, reproduced, may be taken as being representative of these engines, and shows the kind of boiler used with the dome-top firebox and bar frames, distinguishing characteristics of Bury's original practice. In this connection, it is of interest to observe that, when the last of these locomotives were finally withdrawn from service, they were quite possibly the only remaining examples of a former famous type still at work. A further feature in the design of these engines to be noted is the peculiar position of the cylinders, placed low down between the frames so that the piston rods and crosshead slide-bars passed below the leading coupled axle. The valves were in steam chests above the cylinders, rocking levers being used to connect the valve spindles with the valve gear. It may here be pointed out that this cylinder position was retained by Fairbairns after other locomotive builders had discarded it in favour of a higher position between the frames, thus overcoming the obvious disadvantages due to the piston rods being below a leading coupled axle.

The following are the principal dimensions common to all the engines: cylinders 15in by 24in; coupled wheels 4ft 6in diameter; total heating surface 950 square feet; steam pressure 110 lb per square inch; engine weight in working order 21·45 tons; total weight, engine and tender, 36 tons. As previously stated, these locomotives represented Fairbairn's standard practice, retained during the whole of the period the firm was engaged in locomotive building, extending over some twenty-three years, from 1839 to 1862. The Furness engines Nos. 15 and 16 delivered in 1861 were, therefore, amongst the last turned out by Fairbairns, who constructed in all about 400 locomotives, fifty-seven of which were of the Bury class, probably exemplified by the Furness engines.

In concluding these notes, mention may be made of a series of articles contributed to THE ENGINEER entitled "Short Histories of Famous Firms." One, written by the late E. L. Ahrons, which appeared in the issue for February 20, 1920, dealing with William Fairbairn and Sons, gave a summary of the numbers of locomotives built and the countries to which they were delivered.

It may be there are amongst the readers of THE ENGINEER those having some interest in early locomotive history: the writer, therefore, offers the foregoing remarks on some famous engines with which he was at one time acquainted during their last working years. The writer acknowledges indebtedness to Mr. C. R. H. Simpson, for the loan of the photograph of engine No. 13 and for other aid in putting together these notes.

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## Polytetrafluoroethylene

AT an exhibition held recently at its headquarters at Millbank, London, S.W.1, Imperial Chemical Industries, Ltd., drew attention to the wide and expanding applications of the plastic polytetrafluoroethylene (p.t.f.e.) which it manufactures and which is known as "Fluon." Display boards gave technical information about "Fluon" and had mounted upon them finished examples of the material as applied to general engineering products and also to chemical and electrical engineering. For general purposes, the uses of the plastic largely depend upon its low coefficient of friction and non-stick properties. Its use as a low friction material is confined to light loads and low speeds and it is, therefore, useful as a bearing for delicate mechanisms and sensitive instruments. Many examples of this particular form of application were shown and, besides bearings, included sleeving for metal springs, tubes, gaskets, packings, shields and bellows. Few materials will stick to "Fluon" and this non-stick property, which is limited to conditions where loading is not heavy and/or where abrasive conditions are not severe, makes it suitable for employment as roller sleeves, such as for bread dough rollers and paper-making machine rollers, and lining for hoppers. The foregoing properties, together with that of high resistance to chemical attack, makes the material suitable for a large number of applications in the chemical industry such as packings, gaskets, hose, laboratory ware, tubing and seals, examples of which were displayed. Furthermore, "Fluon" besides being the best of solid dielectrics is also a class "C" electrical insulator, and the plastic, which does not degrade on ageing, can withstand soldering iron temperatures and is flexible at low temperature. Examples of employment in the electrical industry covered cables, insulators and other components, valve seats and condenser seals, among many others.

"Fluon" is available as a white free-flowing granular powder or as a milky dispersion of relatively low stability and is an inert, non-toxic thermoplastic made from the basic raw materials fluorspar, sulphuric acid and chloroform. From them "Arcton 4" is derived and the pyrolysis of "Arcton 4" at about 800 deg. Cent. produces the monomer tetrafluoroethylene (t.f.e.) which is scrubbed and fractionated to remove oxygen or compounds containing hydrogen or chlorine. The pure t.f.e. is polymerised under pressure in stainless steel autoclaves in the presence of excess water, which acts as a medium for the transference of the heat generated during the fast and exothermic reaction which is initiated by a water soluble catalyst capable of generating free radicals. The white granular powder form of p.t.f.e. is produced by washing and then drying at a high temperature, while for the production of p.t.f.e. dispersion the polymer is stabilised with surface active agents and then concentrated by electrodecantation.

The white powder is of low bulk density and can be fabricated into solid or wrought forms. There are two transition points, 20 deg. and 327 deg. Cent., and the material has a serviceable temperature range of −100 deg. to 250 deg. Cent., and in certain circumstances to 300 deg. Cent., while it neither absorbs nor is wetted by water. It possesses excellent non-sticking properties and the coefficient of friction is so low that it is practically self-lubricating. Within the temperature range already mentioned, the material is completely resistant to attack from acids, alkalis and solvents except molten alkali metals and fluorine. The electrical properties are claimed to be as good as those of polythene and if arcing occurs no conducting track is left. "Fluon" has poor flow properties and to make simple shapes the general method is to sinter cold preformed powder material. The pressure required for forming ranges from 2000 lb to 3000 lb per square inch and the mould is baked at 360 deg. Cent. for about ninety minutes to cause sintering. Pressure sintering can be carried out, also impact moulding, and the material may be extruded using a die temperature between 400 deg. to 450 deg. Cent. Using standard equipment, it is possible to cut film from 0·001in thick from a block, having a tensile strength of 2000 lb per square inch and an elongation at break of about 150 per cent. Cold rolling can be used to reduce the thickness of the film with a consequent increase in tensile and reduction in elongation at break. Machining operations present no difficulties and the scrap can be disintegrated and reprocessed. The material is non-inflammable and the thermal conductivity is about 2·1 calories per square centimetre per hour for a temperature gradient of 1 deg. Cent. per centimetre. In the following table the more important properties of "Fluon" are recorded:

*Properties of "Fluon"*

| | |
|---|---|
| Tensile strength (pounds per square inch) | 2000 |
| Elongation at break (per cent) | 50–400 |
| Young's modulus (pounds per square inch × $10^5$) | 0·58 |
| Impact strength (Izod) | 4·0 |
| Density (gm. cubic centimetre) | 2·2 |
| Heat resistance (deg. Cent.) | 250–300 |
| Volume resistivity (ohm-cm) | $>10^{18}$ |
| Dielectric strength (volts per mil, $\frac{1}{10}$in sheet) | 500 |
| Dielectric constant | 2·0 |
| Power factor | 0·0001 |
| Surface arc resistance | >100 Does not track |

The values given are typical for moulded pieces and the tensile strength ranges from 1500 lb to 2500 lb per square inch, figures which can be increased to 10,000 lb to 15,000 lb per square inch by cold rolling.

## Ventilated Squirrel-Cage Motors With Class-E Insulation

A NEW range of axially-ventilated squirrel-cage induction motors, with ratings from ½ h.p. to 50 h.p., has been introduced by the English Electric Company, Ltd., Marconi House, Strand, London, W.C.2. These motors, one of which is illustrated, have standard fixing dimensions according to the new British Standard draft specification CW (ELE) 6246, and they make use of class-E insulation which allows a temperature rise of 65 deg. Cent. on 40 deg. Cent. ambient temperature. Because of this increase in permissible temperature rise, smaller and cheaper motors are made possible. The new range of motors (type " C ") will eventually supersede previous designs of machines which were based on a maximum temperature rise of 40 deg. Cent.

To provide a background to the draft specification CW (ELE) 6246, upon which the new range of motors is based, it may be recalled that B.S. 2083 : 1954 established standard ratings and gave the main dimensions for a range of totally-enclosed fan-cooled squirrel-cage induction motors having outputs between 1 h.p. and 25 h.p. and complying with B.S. 168. Then, in 1955, B.S. 2613 was introduced ; it specified electric motors and generators with a " maximum continuous rating," as against the " continuous rating plus overload " specified in B.S. 168, because the former was more in conformity with modern practice. This maximum continuous rating, however, did not apply to ventilated motors having an output less than 50 h.p. per 1000 r.p.m. It was explained that, when the revised table of limits of temperature rise for

**This motor is one of a new range of ventilated squirrel-cage induction motors. Class-E insulation permits a temperature rise of 65 deg. Cent. on 40 deg. Cent. ambient temperature**

the new classes of insulation was published, an extension to B.S. 2613 would be made to include class-E insulation which permits a temperature rise of 65 deg. Cent. on 40 deg. Cent. ambient temperature, taking advantage of the ability of modern insulation to withstand higher temperatures than those previously favoured by British practice. Following the success of motors manufactured to B.S. 2083, it was decided by the British Standards Institution to extend the standardisation of electric motors to those with ventilated enclosures and the draft specification CW (ELE) 6246 has been compiled accordingly.

The American N.E.M.A. standard MGI-1955 has been used as a basis for the draft CW (ELE) 6246 but, for a given frame size, the horsepower outputs and shaft diameters have been increased to accord with the greater outputs available from British practice and from class-E insulation. This draft specification covers foot, flange and skirt mounting, ventilated, squirrel-cage motors (with protected or drip-proof enclosures) having outputs from 1½ h.p. to 50 h.p. on two poles, but four, six and eight poles will also be available on the same frame for operation on three-phase, 50 c/s supplies.

The electrical insulation used in the English Electric type " C " motors is in compliance with class-E insulation as described in B.S. 2757, and is intended to withstand a total temperature of 120 deg. Cent., which allows a margin over the permissible 105 deg. Cent. (=65+40 deg. Cent.).

The conductor wire is covered with an enamel based on polyvinyl-acetal resin, a material which has been proved in service for many years. The coils are mush wound and are enclosed in the core slots by a liner comprising a combination of a cellulose tri-acetate film and press-paper, the press-paper forming the mechanical support for the film. The slot is sealed off with a channel formed from a similar combination material but using " Leatheroid " as the backing to ensure maximum stiffness for the narrow channel. An additional seal on the larger machines is provided in the form of a wedge of phenolic laminated board. The coils are separated in the slot by a channel section of a similar material to the slot seal. On the overhang the insulation between phases is a pad of varnished " Terylene " cloth. The coil lead insulation is a braided " Terylene " sleeve which has been heat-treated, producing a tough and very closely braided sleeve. The sleeve over the coil joints is of braided glass. The terminal leads are of polychloroprene-covered cable, these leads being braced to the overhang with " Terylene " tape.

The whole stator core is impregnated in an oil-modified phenolic varnish, giving good protection against humid conditions and bonding the whole windings into a hard mass. This impregnation is carried out in a continuous, fully-automatic plant by immersing the windings endwise to ensure penetration of the varnish along the whole length of slot and windings and thus excluding air pockets.

The frame and end shields are of cast iron. As illustrated here, the end shields are secured by four bolts and can be turned to any of four positions at 90 deg. intervals to allow the motor to be mounted on floor, wall or ceiling. Cooling air is drawn by a fan through screen-protected ventilating openings in the lower half of one end shield, over the bearing, and is then forced along axial channels between the stator core and frame, before being expelled through ventilating openings in the other end shield. Baffles direct the cooling air over the winding end turns and the bearings.

The rotor, which is carried in metric size bearings, has die-cast conductors and end rings and is dynamically balanced to close limits.

The terminal box can be fitted in any of four aspects, 90 deg. apart, according to the cable entry desired.

## Improved Continuous Mining Machine

AN improved design of continuous mining machine, which has been introduced by Joy-Sullivan, Ltd., of Cappielow, Greenock, to replace the " 4–JCM " machine, is known as the " 1–CM–2 " model. The new machine is stronger in construction and has a higher mining capacity than the previous design, although the general construction and operating principle are similar. It has a possible capacity of 4 tons a minute working in coal seams at least 52in thick.

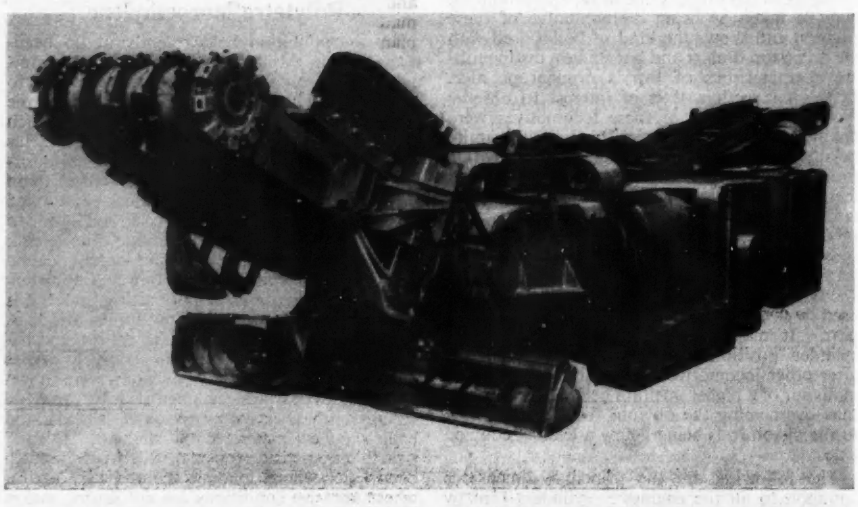
The improved machine is illustrated on this page. Its ripper head and front conveyor are mounted on a turntable on the top of the main chassis and can be swung through about 35 deg. on either side of the centre. The chassis is carried on crawler tracks driven by two 7½ h.p. motors and at its rear the controls, motors and contactor gear are mounted. A rear conveyor which can swing 45 deg. on either side of the centre line is used to discharge the coal into pit transport.

The standard machine is equipped with a 5ft 6in multiple chain ripper bar, which has five forged chains with nine bit positions, and double bit blocks. Two 3in heads carrying bits are mounted on the bar to reduce side pressure on the outside chains. Two 65 h.p. water-cooled main motors drive the ripper head through bevel and helical gearing, and it is positioned by double-acting, hydraulic shear jacks to cut up to 102in above floor level. Two 3 h.p. motors drive the 21in rear conveyor through heavy-duty bevel and spur gears and slipping clutches, to give protection in the event of jamming or stalling by overload. A heavy-duty clutch is fitted to protect the clean-up scrolls which have been increased in size for the new machine and are now driven mechanically and not hydraulically as before. A single 15 h.p. motor-driven pump supplies fluid to the hydraulic system, and all of the piping and electrical cables are now channelled through the centre of the machine in the turntable, to reduce their movement to a minimum.

A further " 1–CM–2B " model of the machine is provided with two roof bolting drills equipped with dust collector apparatus. The drills, controls, drill pump and motor, special cross tie, long rear conveyors, and special timber jack mountings of this machine increase the overall height from 45in to 63in, the width from 92in to 117in, and the length from 28ft 6in to 29ft 8½in as compared with the standard machine. A hydraulically operated auger design drill on each side of this model is pivotally mounted on the crawler frame and can be swung through 30 deg. inboard and 24 deg. outboard from the vertical.

Each drill has a feed travel of 36in and has two speed ranges. The fast range up to 586 r.p.m. is used for maximum drilling speed, and the low-speed range of 0 to 293 r.p.m. is used for tightening high torque bolts. The same spindle is used for carrying both the auger steel when drilling and the extension bar when bolting.

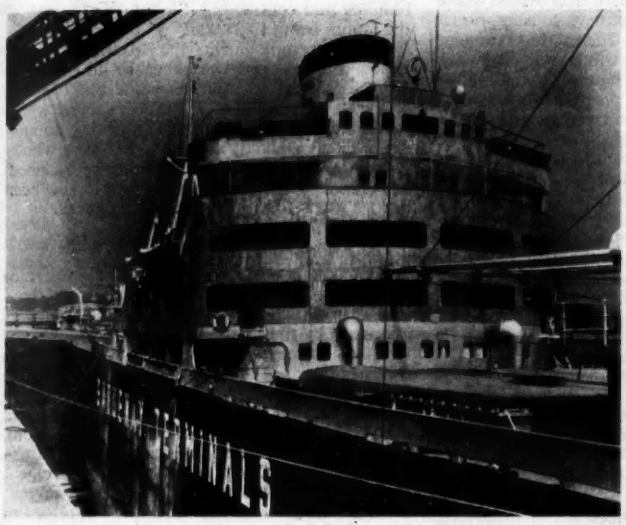
The dust collector collects drillings from the roof drills, conveys them through a 2in hose and deposits them in cans equipped with a shaker lever for freeing the particles from the filter bag. The drill steels work through collector cups which can be adjusted according to the roof height and the dust collector motor starts from the same switch as the hydraulic supply pump motor of the drill. A special large ripper head with a bar 7ft long giving a cutting height of 120in can be fitted to the machine if required.



**Improved design of continuous mining machine for working in coal seams of 52 inches and over. It is fitted with a 5 ft 6 in ripper bar and the ripper head is driven by two 65 h.p. water-cooled motors**

## Unpainted Aluminium Alloy Ship Superstructure

It was more than two years ago that Saguenay Terminals, Ltd., took delivery, on long term charter, of the S.S. "Sunrip," which was built by Davie Shipbuilding, Ltd., Quebec, and designed principally for the bulk transport of alumina or grain, although provision was made for other cargoes to be carried. The main particulars of the ship are: length between perpendiculars, 450ft; breadth moulded, 62ft 6in; depth to upper deck, 40ft 8in; draught, 29ft 2¾in; deadweight, 12,825 tons; displacement, 17,165 tons, and capacity for heavy bulk cargoes, 493,286 cubic feet. The ship is almost completely welded and incorporates a number of design features which enable it to achieve versatility in carrying cargoes; movable panels in the 'tween decks, when in place, form feeders to the holds from the upper deck. Apart from such considerations of general design, the items of interest in the construction of the ship are the midship and aft deck-houses which are built of aluminium alloy and are all welded.




Midship deck-house of the "Sunrip" looking from the starboard bow

The transport of alumina in bulk places a premium on the deadweight of a ship and, consequently, its earning power, and it was this aspect of the situation which gave rise to the consideration of saving lightweight by the employment of aluminium alloys. Light metal had already been decided upon for the funnel and lifeboats but after careful examination of the increased cost balanced against the weight saved and the resultant increased earnings, it was decided to use light alloy for the two deck-houses, hatch beams and covers, boat davits, piping and a number of miscellaneous items. The Aluminium Company of Canada, Ltd., supplied the aluminium alloys and the various amounts for the various items, together with the corresponding savings in weight, are set out in the following table.

| Constructional item | Weight of aluminium | Weight saved |
|---|---|---|
| Midship deck-house ... ... ... | 64·0 | 104·0 |
| Aft deck-house ... ... ... ... | 9·0 | 19·0 |
| Funnel ... ... ... ... ... ... | 2·0 | 4·0 |
| Hatch beams ... ... ... ... ... | 15·0 | 11·0 |
| Hatch covers ... ... ... ... ... | 15·5 | 22·5 |
| Lifeboats ... ... ... ... ... ... | 2·5 | 3·0 |
| Davits ... ... ... ... ... ... | 1·5 | 2·5 |
| Ventilation trunking ... ... ... | 0·75 | 1·5 |
| Windows ... ... ... ... ... ... | 0·75 | 1·5 |
| Piping: | | |
| Air and sounding, bilge and ballast, fire and wash-down, and fresh water | 12·25 | 27·0 |
| Miscellaneous: | | |
| Ladders, awning supports, guard rails, engine-room floor plates | 12·0 | 21·0 |
| Totals, short tons... ... ... ... | 135·8 | 228·4 |

The incorporation of 136 short tons of aluminium alloys resulted in a decrease in the lightweight, or increase in the deadweight, of 200 tons, and it was estimated that the additional cost would be paid for in a period of eight years.

The midship deck-house is 80ft in length by 62ft wide at the upper deck and 39ft high to the top of the compass platform; being about 17 per cent of the ship's length, it was considered as not contributing to the longitudinal strength of the ship, while any notch effect would be minimised by the low modulus of the aluminium alloy. Aluminium magnesium alloys were used in conformity with the requirements of Lloyd's Register of Shipping and the welded design adopted resulted in an aluminium to steel ratio of about 0·38 to 1. Welded as against riveted construction effected a saving in weight of 20 per cent and a saving in cost of 21 per cent. Special care and precautions were taken at joints between dissimilar metals and synthetic rubbers were used as insulating compounds. The deck-house is connected to the upper deck by a steel plate coaming, about 42in high, by an internal aluminium alloy strap, welded to the house and connected by hot-driven steel rivets to the coaming, the faying surfaces being primed with zinc chromate and coated with neoprene paste.

Of considerable interest is the fact that the surfaces exposed to the weather have been left unpainted; although the external appearance is not so pleasing as when painted, there is a considerable saving in maintenance costs, only occasional washing-down being required.

The ship, which has now been in service for more than two years, recently arrived at Avonmouth with a cargo of grain, which provided an opportunity to inspect the condition of the aluminium alloy superstructures and fittings. In service the ship carries raw materials from Kingston, Jamaica, to the smelting plant of the Aluminium Company of Canada, Ltd., at Kitimat, British Columbia, with other voyages, including Atlantic crossings, as cargo offers. Such service involves most climatic conditions from extreme heat to extreme cold, and an inspection of the superstructure showed that the alloys were in excellent condition and did not require any protection by painting. The whole of the surface was covered with a protective skin of aluminium oxide and at points where dissimilar metals were used, such as stainless steel window connections, there was practically no evidence of galvanic action. However, it was noted that the aluminium alloy supports at the derrick crutches had suffered some attack in the region of the top bracket, which is of steel. This trouble could be eliminated since there appears to be no reason why the whole of the crutch should not be of light metal. The main scantlings of the material used in the deck-house are side plating 0·20in to 0·31in, deck plating 0·20in to 0·28in, deck beams, 3in by 3in by 0·19in to 6in by 3in by ⅜in, bulwarks 0·25in.

The limits placed upon permissible deflection of the all-welded hatch beams reduced the advantages of using aluminium alloy, so that the weight ratio of aluminium to steel was 0·575 to 1. The beams, constructed of 0·60in webs with a depth at centre of 28in and face plates of 9½in by 1in, appeared to be in good condition, as were the portable hatch covers, which were fabricated from ¼in sheet and 3in by 1in by 1in by ¼in channels and are completely closed so that they will float. A passing inspection of the davits did not reveal any visible attack and similar remarks apply generally to the condition of the awning stanchions, guard-rails and other miscellanea.

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## Railway Wagon Haulage Equipment

Particulars have been received from the National Coal Board of an equipment which has been developed and installed at Calverton Colliery for moving and "spotting" the new standard railway wagons being introduced by British Railways.

The design is a modification of existing equipment in use at the colliery which is not suitable for the new 40-ton hopper-bogie wagons and the new 24½-ton vacuum-braked wagons. The equipment has a very low initial height, which allows it to clear the brake gear on the new wagons when its arms are in the retracted position. It incorporates an axle-counting device, which is essential when mixed wagons are handled.

Standard equipment for moving railway wagons, developed at Calverton colliery, shown with arms in hauling position

As can be seen in the accompanying illustration, the equipment consists of a bogie which is hauled backwards and forwards on separate flat tracks set between the rails of the main railway track. It is hauled by an electric winch through wire ropes. The arms, which are designed to allow engagement on wagon axles at varying distances above the rail level, are connected by link bars to the sliding drawbar to which the haulage ropes are fixed.

A counting device forming an integral part of the bogie ensures that the arms engage on a predetermined axle. In it a contact bar is attached to the spotter arms through spring-loaded plungers, which are depressed by the flanges of the wagon wheels and operate a switch. An electric circuit is arranged so that when this switch has operated four times the bogie stops and is ready for re-engagement on forward travel. Current for operating the switch is provided through a contact sliding on a live rail by the bogie track.

The machine is under the control of the wagon operator for forward movement only When it is required to move wagons forward a push button is operated to start the electric winch, and when the machine reaches the limit of its forward travel it is automatically reversed. On the reverse travel, after four wagon wheels have been counted, the machine stops and is again ready to move the wagons forward.

# Industrial and Labour Notes

### Industrial Disputes

In the early part of last week, the Electrical Power Engineers' Association announced its intention of instructing its members employed in the Central Electricity Authority's generating stations to "work to rule," following the breakdown of salary negotiations. The Association's membership is broadly described as the technical staff of power stations, apart from plant operatives. For some time, the Association has been pressing for the restoration of salary differentials that existed in 1948, but the Central Electricity Authority has said that there have been no negotiations on that matter for more than a year. The Association has also been seeking upgrading of some classes of power station staffs whose responsibilities have increased through technical developments. On Thursday of last week, the Minister of Labour was questioned in Parliament about the dispute. In his reply, he said that although "trade union procedure" had not been exhausted, he was ready to see whether, and, if so, how his department could best be of service. Subsequently, after discussion with Ministry of Labour officials, it was stated that both sides had agreed to an examination of the dispute by an arbitration board.

Another industrial dispute which is attracting a good deal of attention is that at the Dagenham works of Briggs Motor Bodies, Ltd., a subsidiary of the Ford Motor Company, Ltd. Some weeks ago, the company dismissed a shop steward for what it holds was a breach of agreed discipline, but since then there has been considerable union pressure for his reinstatement. The company has stated that it cannot alter its decision. At the end of last week, the Amalgamated Engineering Union conducted a ballot amongst its members at the Briggs plant to discover whether there would be support for official strike action. The result of this ballot showed that there was the necessary two-thirds majority in favour of a strike. On Monday, the executive of the A.E.U. met to consider the matter further in the light of the ballot. A statement issued after it said that, unless the firm was prepared to reinstate the dismissed man, the A.E.U. would call an official strike at the Briggs plant to begin on Wednesday next. Meanwhile, members of the A.E.U. executive and representatives of the Ford Motor Company, Ltd., have had separate conversations with conciliation officers of the Ministry of Labour.

### Coal Miners' Bonus

Towards the end of last year, the National Coal Board and the executive of the National Union of Mineworkers agreed to defer, for six months, consideration of a claim for the complete removal of the disqualifications attaching to payment of the five-day week bonus. At the same time, it was agreed that during the six-month period there should be tried an arrangement whereby a miner with five consecutive weeks' good attendance who missed one shift (except through a strike) in a week which was otherwise fully worked, should not lose the proportionate bonus for the days in that week on which he had worked.

That arrangement, however, was subject to ratification by a coalfield vote of the union. It was an arrangement that did not receive the union's full support. On Thursday of last week, the National Coal Board and the executive committee of the union met again to discuss the five-day week bonus. The union agreed to put to a delegate conference, a proposal which the Board said it was able to make "in the light of the recent production and attendance record." The proposal is that the Coal Board would agree to concede the union's claim as at June 1, 1957 (except in respect of shifts lost because of strikes), provided the union gives effective support to the Board's efforts for the recruitment and placing of British workers, or, where not available, foreign workers to fill existing vacancies subject to the terms of the 1947 agreement. The proposal has been made also on the basis of the union's undertaking to start a campaign at once for regular attendance, fewer strikes and improved output, and to continue that activity should any deterioration occur in any coalfield.

### Iron and Steel

British steel production during January averaged 415,900 tons a week, which was 10,700 tons above the average for January last year. The year has begun, therefore, with steel output running at an annual rate of 21,627,000 tons. Pig iron production in January, averaging 256,900 tons a week, was a little lower than a year earlier, the decline being accounted for mainly by the temporary closure for repairs of a blast-furnace in South Wales.

The Iron and Steel Board has issued some figures showing the "apparent consumption" of finished steel last year. The total for the year is put at 13,524,000 tons, which was 2300 tons higher than in 1955. The figures quoted for the last quarter of 1956 are provisional, but they indicate some falling off in consumption during that period. This change, the Board says, appears to be due partly to less steel being used to increase the volume of work in progress in the metal-using industries than a year earlier, when consumption for that purpose was exceptionally high. The decline in the last quarter of 1956 also reflects a change in the pattern of consumption, as many of the capital equipment and exporting industries are increasing their use of steel, while the industries making durable consumer goods have been taking less. The Board's opinion is, however, that this check to the expansion of steel consumption may not last long. There has been a sharp fall in steel imports following the change in consumption. In the fourth quarter of 1956 steel imports amounted to 160,000 tons, compared with 313,000 tons in the corresponding quarter of 1955.

### Steel Prices

In his chairman's statement at the annual meeting of the Lancashire Steel Corporation, Ltd., on February 12, Sir John James commented on the unfortunate effect of arbitrary price-fixing policies in the steel industry. As an example, Sir John mentioned the extreme and continuing shortage of steel plates, which, he said, had hampered the efforts of British shipbuilders to give reasonable delivery against foreign competition. There was also the shortage of heavy sections which had delayed construction urgently needed for the expansion of the country's basic industries.

Those shortages had no doubt arisen in the first instance, Sir John suggested, through the impact of full employment on an industry which before the war produced only from 10,000,000 to 11,000,000 tons of steel a year, against 21,000,000 tons to-day. But, in his opinion, Sir John added, the continuation of these shortages over the past twelve years was largely the direct result of the inadequate return which had been allowed on such products. As a consequence, the steel firms had naturally felt reluctant to install the enormously expensive machinery necessary to produce plates and heavy sections in the volume required to-day.

Sir John went on to remark that the time was overdue for a complete review of and new thinking over the principles on which price-fixing in the steel industry was based. The whole future well-being and power of expansion of that great industry, he said, depended upon a reasonably remunerative return, out of which money could be ploughed back to help in financing improvement and development, and at the same time provide a reasonable return on invested capital.

### Employment and Unemployment

The Ministry of Labour's latest report on the employment situation in Great Britain says that at the end of December last there were 22,989,000 people (15,227,000 men and 7,762,000 women) in civil occupations. This was 189,000 fewer than a month earlier, a greater fall, the Ministry says, than normally occurs at this time of the year. Over the whole of last year, the number in civil employment fell by 60,000, all women. There was a decline of 125,000 in the number employed in the manufacturing industries—mainly the industries producing consumer goods—and small increases over the year in most of the other industry groups.

In the manufacturing industries during December, the number employed in the engineering, metal goods and precision instruments group fell by 10,000 to 2,808,000, and in vehicle building the number employed declined by 15,000 to a total of 1,208,000. In other industries and services, the principal change in December was a decline of 42,000 in the number employed in building and contracting, the total at the end of the month being 1,491,000.

As to unemployment, the Ministry's report shows that between December 10 and January 14, the number of insured people out of work rose by 85,658 to a total of 382,605, a figure which represented 1·8 per cent of the working population. Of the January total, 342,489 were wholly unemployed and 40,116 temporarily stopped, 38 per cent of the wholly unemployed having been out of work for more than eight weeks.

### Industry and European Free Trade

The annual general meeting of members of the Federation of British Industries in Scotland was held in Glasgow last Tuesday, and was addressed by the president of the Federation, Sir Graham Hayman. In his address, Sir Graham commented on the Government's decision to enter into negotiations for a free trade area in Europe. It was a decision, he said, which had been based on the conviction that it would, overall, serve the best interests of the British economy. Although industry had divergent views, a substantial proportion was in favour, some on the grounds that we could not afford to be excluded from an economic integration of Europe, while others felt that the proposals offered great prospects of expanding trade.

Sir Graham went on to say that the European free trade area proposals might be classified under the respective headings of inevitability or opportunity; but they were undoubtedly of imponderable significance and would call for the fullest use of our materials and manpower. There were also important safeguards to be established at the outset, and the Federation had set up a special working party, on which the Association of British Chambers of Commerce and the National Union of Manufacturers were also represented. That group, Sir Graham explained, was in constant touch with the Board of Trade, so that regular consultation between Government and industry was assured. As the negotiations so far had already revealed, all the potential partners in the free trade area faced the prospect of far-reaching adjustments within their individual economies. But, Sir Graham added, it should be remembered that the time-table of twelve to fifteen years was being devised to allow those changes to take place with the least possible disruption.

It was sometimes suggested, Sir Graham continued, that the European free trade scheme would tend to eliminate the small firms in Britain, many of which played such an important part in our economy. It must be remembered, however, that the pattern of industry in Europe was similar, and whilst changes would be inevitable, there was no reason to write off in advance the effective competition which could be provided by the small firms. This, Sir Graham urged, presupposed at least one question of fundamental importance, namely, the continual attempt to increase productivity. In some quarters, Sir Graham remarked, it was felt that productivity and work study were mainly the province of larger firms. That was not so, and the stimulus and guidance provided by the British Productivity Council should be seized by all sizes of firms in the certain knowledge that good results could be achieved.

# Finnish Flour Mill

A NEW milling plant of the Finnish Co-operative Wholesale Society, O.T.K. (Osuustukkukauppa, Helsinki) was opened last year. It is situated at Hameenlinna, some 80 miles north of Helsinki, on the main railway line to Tampere. The mill was built to the functional specifications provided by the project engineers and designers of Thomas Robinson and Son, Ltd., Railway Works, Rochdale. This firm also supplied all the principal equipment. The plant (Fig. 1) comprises cleaning, milling and packing departments, a warehouse and grain and flour silos. The main departments are housed in a ten-storey block with an in-line layout, the milling plant being arranged in two completely separate sections, a flour and a rye mill.

*Silo.*—The fully automatic silo and the twelve-storey working house are opposite the mill across the railway track. There are thirty-two main circular reinforced concrete bins in four rows of eight, with twenty-one interspace bins, the total capacity of the group being 12,240 metric tons.

The main intake is by a 60-ton pneumatic plant withdrawing from either road or rail wagons. Luffing booms and telescopic intake pipes are capable of coping with the 40ft long Russian boxcars which deliver a high proportion of the mill's wheat supplies. The intake discharges through a receiver to the main intake elevators, which are also fed by a totally enclosed chain conveyor with a capacity of 30 tons an hour, serving the twin rail tracks and road vehicles.

Automatic alarms are fitted to every elevator boot. Immediately a slip occurs between the belt and the terminal pulley, the elevator motor is cut out. Thus the possibility of a fire as a result of friction caused by a choke is eliminated. The plant is very fully interlinked and overflow spouts come into play throughout the plant in an emergency.

The intake elevator feeds a 1000 kg tip weigher followed by a rubble separator and a cyclo-pneumatic separator.

As an alternative, the 30-ton intake can feed to a secondary intake, weighing and cleaning plant, consisting of a 300 kg tip weigher and an intake separator. This plant is fed by a working bin fitted with high and low-level indicators controlling the feed motors. After preliminary cleaning, the grain from both the 60- and 30-ton intakes is transferred to the main bins by totally enclosed chain conveyors. A damper, with the necessary by-pass runs, is incorporated at this point.

The feed to every bin is monitored by means of a "Mark II" spout flow indicator, which cuts off preceding equipment immediately the flow fails.

The bins themselves illustrate the latest silo practice. Temperatures can be measured at three positions in each bin and recorded, and may be checked instantly from a central control point at the press of a button. Turnover runs are provided so that any parcel of grain can be re-treated in the preliminary cleaning plant when necessary. In addition, every bin is fitted with a system of vertical ventilation.

The turnover runs are also arranged to feed a "Model MOm" drying plant by way of a balance bin fitted with high and low-level indicators. The dryer feeds a balance bin, similarly fitted with high and low-level controls. Hot air is provided by Serck steam heaters fed from the central generating plant. Outloading facilities of 30 tons an hour comprise a controlled balance bin feeding a check weigher. A totally enclosed metal-cased chain conveyor carries the grain to the mill through the branch tunnel.

Prefabricated metal spouting throughout the silo was manufactured in Finland to Robinson specifications.

*Screen Room.*—The 5-ton screen room is equipped throughout with "Pneu-Flow" conveying and the "Pneu-Spout" system. Machinery is all-metal and was designed to take full advantage of pneumatic conveying techniques. Wheat is delivered from the silo at a rate of between 30 and 35 tons an hour and fed to a nest of ten dirty-wheat bins, each capable of holding 60 tons. Damping can be applied by an independently metered pump controlled by the flow of grain. Grain is withdrawn by a battery of volumetric measurers, elevated pneumatically to a "Model PFm" receiver-aspirator, and spouted by way of an automatic damper to the first of the screen-room machines, a "Model PZm" double pneu-separator. This is followed by a battery of cylinders: one cockle, one recockle, and one oat and barley, which is also paired with a re-treat cylinder. Small wheat from the cockle and recockle cylinders is retrieved by a pair of spiral seed separators and bagged off separately, or elevated to the conditioning bins. Oats and barley from the second re-treat are bagged off.

Any metallic particles are removed by box magnets and the main wheat stream passes to the second "Pneu-Flow" machine, the "Model PRm" scourer. A by-pass spout to the lifting section is provided for feeds which do not require scouring.

The wheat is elevated pneumatically to the second receiver-aspirator on the top floor, which feeds down to a three-stage washing plant. After adding moisture as required, the grain passes to a "Model JOm" hot air conditioner. This machine is fed by large hot air heaters designed for operation with the low pressure steam from the power generating station. After conditioning, the wheat is stored in a nest of reinforced concrete bins with a total capacity of 600 tons.

From these bins wheat is withdrawn to the third machine, the "Model PBm" wheat brush, through a further battery of volumetric measurers. The flow is monitored by spout flow indicators which register the readings on a central indicator board, trigger an alarm if the flow of wheat from any bin fails, and stop the feeders.

Direct-lift vertical elevation finally carries the wheat to the last of the receiver-aspirators which feeds to an atomising damper. It is then spouted to a balance bin fitted with high and low-level registering indicators and providing a lie of approximately two hours. The balance bin serves a 50 kg tip weigher, recording the quantity of wheat passing to the first break, by way of a final volumetric measurer and a set of box magnets.

*Flour Mill.*—The 100-tons-per-hour flour mill occupies five floors of the building immediately above the sack warehouse. The layout of the main machinery floors is symmetrical, and ample access has been provided round the machines. Horizontal conveying is reduced to a minimum. By saving a floor beneath the roller floor, it has been possible to adopt the popular Continental practice of having a spout floor between the plan sifters (Fig. 2) and rolls.

The building was designed to house two

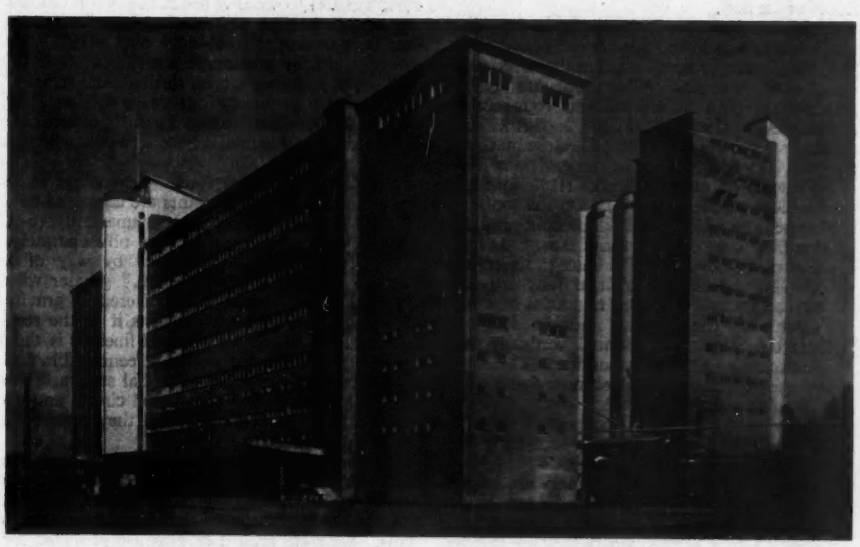


**Fig. 1—The Hameenlinna flour mill of O.T.K., showing the 10-storey bulk storage building, mill, and silos**

**Fig. 2—Some of the twelve square-sieve plan sifters in the O.T.K. mill at Hameenlinna**

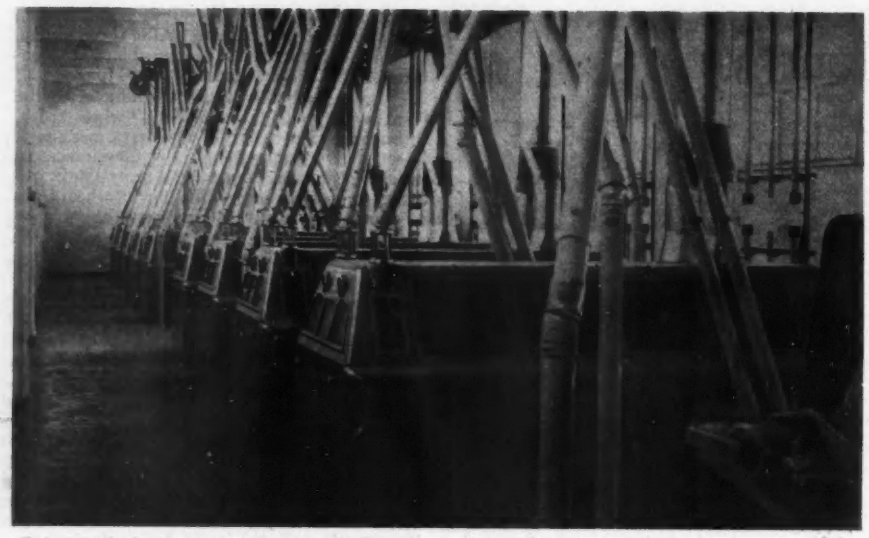


Fig. 3—The nine purifiers are of all-metal construction and are totally enclosed

" Pneu-Flow " units. A grilled slot in the centre of all floors permitted a very neat in-line layout of the vertical pneumatic tubes. The grilling has the effect also of equalising pressures on all floors of the mill.

Altogether, there are fourteen stands, providing six break passages, and sixteen reduction stands providing five coarse and eight fine passages. On the plan sifter floor are twelve square-sieve plan sifters of the four-section, sixteen-sieve pattern (Fig. 2). A further two machines serve the rye plant. All these machines are individually driven. The purifier floor has a complement of nine " Mark III " all-metal double-sieve purifiers (Fig. 3). On the top floor are housed the pneumatic cyclone collectors, the suction filter dust collectors and fans. Air from the dust collectors can be fed back to the mill to reduce heat losses. Centrifugal fans are used for the conveyance of stocks, and axial flow fans for exhausting the purifiers and the dust collectors; the latter are mounted vertically in a penthouse running the length of the mill.

Because water normally does more damage in a mill than the fire itself, there is no sprinkler system ; instead there is a network of sensitive alarms backed up by a twenty-four-hour fire-fighting service.

For powder feeding, the powders are carried by pipeline from a battery of six feeders, under pressure created by a Rootes blower, to the appropriate flour worms, where they are injected in a finely divided spray into the flours.

*30-Ton Self-contained Rye Mill.*—Side by side with the flour mill and matching it in styling, layout and equipment, is a 25–30-ton rye plant. Cleaning is carried out by an all-pneumatic " Pneu-Flow " screen-room ; five 40in " Pneu-rolls" (Fig. 4) provide five break and two middlings passages ; grading and dressing is performed on two four-section, sixteen-sieve plan sifters. The rye mill is fully pneumatic and " Pneu-Spout " unit metal spouting is used throughout. Dust is collected by a twenty-four-sleeve suction filter and axial flow fan backed by a " policeman " cyclone on the pneumatic system to deal with rye fibres.

*Combined Screenings Plant.*—Screenings from both the wheat and rye plants are conveyed to a central point and elevated pneumatically to a grading reel. Rubble is tailed off separately. Coarse screenings are delivered by way of a balance bin to a " Model FNm " grinder with electronic feed control, and delivered by gravity to the original lift which returns it to the reel. Material ground to the required fineness is then passed through to the ground screenings bin and finally re-elevated to the mill offal stream. The disposal plant works on a closed circuit and no screenings reach mill offal until they have been sufficiently reduced.

*Finished Product Store.*—All flour leaving the mill is " entoleted," i.e. any insects or eggs are killed by shredding. It is then weighed and pneumatically transferred to integral bulk storage bins. Separate groups of bins are provided for the various grades of flour, the rye meal, and the bran, to a total capacity of 2000 tons. Every bin is fitted with high- and low-level indicators so that the storage position can be seen at a glance on a central control panel.

Material from the bins is elevated to the packing section, flour first passing through a battery of two-tier Rexman screen redressers. Full facilities are provided for turning over products from bin to bin, and for blending.

The packing equipment includes three valve packers, a small bag packer and two open-mouth bag packers for flour, rye meal and bran. A completely dust-free atmosphere is maintained in the warehouse by exhausting the bins and equipment to filter dust collectors.

The finished product warehouse has direct access to rail on the one side and road on the other. Beneath the packing, milling and cleaning sections is a long spiral-chute warehouse. Bagged products are conveyed directly to storage chutes delivering out to road or rail, where up to fourteen vehicles or wagons can be loaded at the same time.

Fig. 4—Five roller mills, model " MEm " serve the rye mill

## International Course in Hydraulic Engineering

It is announced by the Netherlands Universities Foundation for International Co-operation (N.U.F.F.I.C.) that a one-year's course in hydraulic engineering will be offered to engineering graduates from all over the world, beginning in October, 1957. The course is a joint venture of Delft Technological University and the Foundation. It is hoped that it will lead to a fruitful interchange of ideas in a field in which experience of long-standing and well-organised academic treatment are available in the Netherlands. There will also be the opportunity of seeing and studying the extensive Dutch hydraulic engineering projects which are now under construction or will be launched in the next few years. The chairman of the Faculty at Delft is Professor Ir. J. Th. Thijsse. The teaching staff for the course has been selected from among prominent engineers on the staff of Delft University, the Netherlands Government, and industry. Final applications should be submitted before July 15, 1957, on the appropriate forms ; full information will be given by the Netherlands Universities Foundation for International Co-operation, The Hague, 27, Molenstraat.

## French Shipbuilding in 1956

During 1956, the French shipyards delivered a total of 66 ships of 301,446 tons gross, which compares with 345,747 tons gross completed in 1955. The total included 1 passenger liner of 13,724 tons, 6 oil tankers of 122,327 tons, 34 cargo ships of 129,355 tons, 4 fruit carriers of 19,300 tons, also 16 trawlers and 4 tugs and 2 other craft. Among the ships launched during the year there was 1 passenger liner of 12,460 tons gross, 6 oil tankers of 103,941 tons, 35 cargo ships of 147,824 tons, 5 fruit carriers of 23,450 tons, also 16 trawlers and 3 tugs, making a total of 306,963 tons gross, against the 1955 total of 321,898 tons. The keels were laid for 7 oil tankers of 171,562 tons, 1 ore carrier of 12,000 tons, 33 cargo ships of 169,092 tons, 3 fruit carriers of 12,900 tons, also 11 trawlers and 3 tugs, representing a total of 373,245 tons gross, and an increase of 66,347 tons over 1955.

## International Building Exhibition, Berlin, 1957

From July 6 to September 29 the " Interbau, Berlin, 1957," International Building Exhibition will show the rebuilding of the Hansa quarter, at the western edge of the Tiergarten. This district, prior to its destruction in the war, housed some 6000 people in congested four-storey blocks of flats. The whole area is being redeveloped as a unit with the object of providing variety of design and the maximum of open space. The exhibition will show the various kinds of building in all stages of construction. From September 14 to 29 the " Interbau " Building Industries Exhibition will be held at the Funkturm exhibition grounds, which provide 504,000 square feet of floor space in twelve halls and nearly 1,500,000 square feet of open space. For further information, application should be made to the Central Office, Heerstrasse 18-20 Berlin-Charlottenburg 9 (telephone 920186).

# Tenth Anniversary of the U.S. Atomic Energy Commission

BY OUR AMERICAN EDITOR

TEN years ago, at midnight on December 31, 1946, the newly-created civilian United States Atomic Energy Commission assumed the responsibility for the American atomic energy programme. At that hour, the enterprise managed by the wartime Manhattan Engineer District, U.S. Army Corps of Engineers, was transferred officially to the Atomic Energy Commission. Chief among the military agency's assets were large research laboratories and works created in haste under wartime pressures. In these installations, the civilian-military team had built large plutonium plants based on the sustained fission chain reaction achieved by the Enrico Fermi group in the world's first reactor, they had separated the isotopes of uranium, designed and produced the first atomic weapons, initiated the first studies in nuclear power and begun distribution of the atom's most important by-product to date—the radioactive isotope.

The transfer was authorised by the first American Atomic Energy Act which became law on August 1, 1946. The next day, pursuant to the Act, the Joint Congressional Committee on Atomic Energy was organised. The close statutory relationship of the executive and legislative branches in the area of the national atomic energy programme has been maintained by daily liaison, numerous hearings, and by a continuous flow of unclassified and secret information from the Commission to the Committee. To-day, ten years later, the objectives of the United States nuclear programme remain basically unchanged. They are to make the maximum contribution to the common defence and security and develop the applications of nuclear energy so as to promote world peace, improve the general welfare, and strengthen free competition in private enterprise. The progress toward these goals in the 1947–1956 decade has been speeded by a flexible partnership between government, academic and research institutions and American industry. It seems appropriate on this tenth anniversary of the Atomic Energy Commission to review briefly some of the achievements of this partnership ; a few of the activities are illustrated on the page opposite.

### 1947 TO 1949

The first period from 1947 to 1949 was one of rehabilitation, reorganisation and recruitment. Primary effort was devoted to putting the manufacture of fissionable material and the weapons development programme on a permanent basis. A crisis in the production of plutonium in the Hanford, Washington, reactors was overcome and the efficiency of these reactors increased. The weapons testing ground at Eniwetok in the Pacific was set up, three new weapons designs were tested in 1948, and weapons manufacture was put on an industrial basis in 1949. Intensive studies were launched to discover more uranium in the United States and to develop practical methods of processing low-grade ores. The scientific, engineering and technical staffs of the Commission were strengthened and plans made for a 1250 million dollars expansion programme. Included in it were millions of dollars in permanent housing for the three " atomic cities " of Oak Ridge (Tennessee), Richland (Washington), and Los Alamos (New Mexico).

The foundations for steady advances in reactor technology were laid with the authorisation of the experimental breeder reactor, the expansion of the ship propulsion and materials testing reactor projects and the selection of a large area in Idaho for a national reactor testing station. The availability of a plentiful supply of radioactive isotopes gave scientists a valuable new tool for research in a wide variety of fields and for application in medical diagnosis and therapy. By the end of 1949, nearly 10,000 shipments of isotopes had been made to institutions in the U.S.A. and 700 to twenty-six other countries.

On February 21, 1948, occurred what was considered the most important advance in nuclear science since the discovery of fission in the late 'thirties—the artificial production and the observation of the meson, a primary nuclear particle. In this year, also, plans were laid for particle accelerators in the 1000-million-volt range to be built at the Brookhaven National Laboratory, New York, and at the University of California Radiation Laboratory at Berkeley, California. Thus, the overall programme was well under way when the detection of a Soviet explosion or test in August, 1949, emphasised the fact that another country now had a capability in nuclear weapons. The Congress immediately authorised the acceleration of construction of some major facilities that were then planned or under way.

### 1950 TO 1953

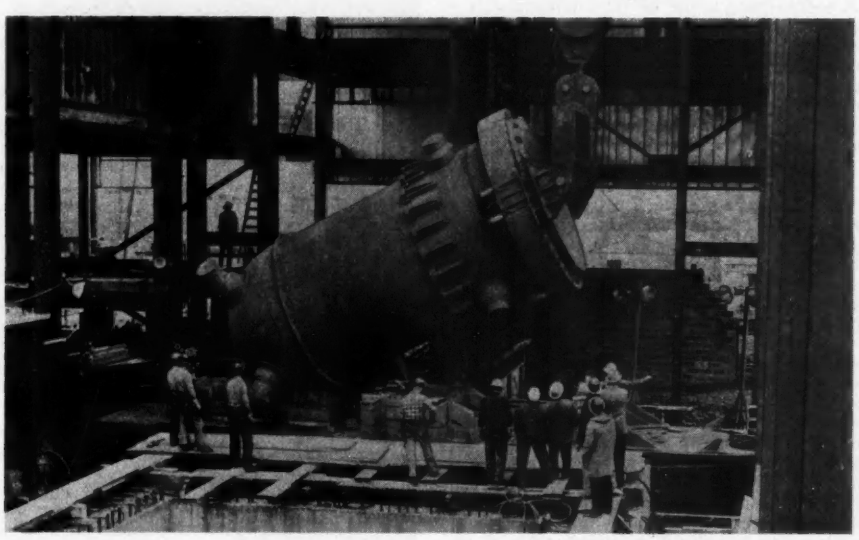
In the next four years, a very large expansion in all phases of the programme took place. The Congress authorised an expenditure of more than 3000 million dollars for new installations. Work began on the expansion of the capacity for the separation of uranium 235 with new gaseous diffusion plants at Paducah, Kentucky ; Portsmouth, Ohio, and additions to the Oak Ridge, Tennessee, plants ; together with the expansion of the production capacity for plutonium at Hanford, Washington. During much of this period, A.E.C. construction accounted for more than 3 per cent of all U.S. construction, both in dollar value and in the labour force employed.

On January 31, 1950, the President directed the Commission to proceed to develop thermonuclear weapons. Before the year ended, the site for the Savannah River, South Carolina, works had been selected. To accelerate weapon development, a continental testing site in Nevada was established in 1950, and a new weapons laboratory at Livermore, California, was authorised in 1952. The several series of weapons tests in 1951–1953 made it possible to develop tactical as well as strategic nuclear bombs and to make a " family of weapons " adapted to the specific needs of various branches of the armed services. Experiments contributing to thermonuclear weapons research were included in the 1951–1953 tests. A steady improvement in the efficiency of production of plutonium and uranium-235 resulted in new records being set up each year and in unit costs being lowered.

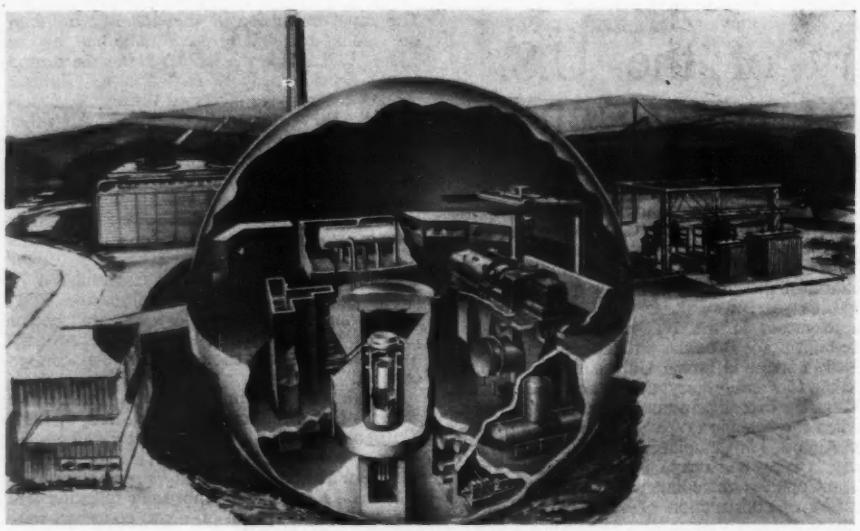
The rapid expansion of the domestic uranium ore mining and milling programme had, by the end of 1951, made the United States the second largest world producer of uranium. Foreign sources of ore were increased through contracts with South Africa and Australia. All other phases of the atomic programme gathered momentum. The experimental breeder reactor was completed in Idaho and in December, 1951, produced the world's first useful electric power from a nuclear reactor. The powerful materials testing reactor also went into operation at the Idaho site. The Oak Ridge School of Reactor Technology was established. Construction of the land-based submarine thermal reactor (STR) was advanced and several experimental reactor projects were authorised, including the development of the sodium-cooled, graphite-moderated concept.

The industrial applications of radioactive isotopes began to increase rapidly, and, in 1951, a surge of industrial and popular interest in nuclear power resulted in the inauguration of the Commission's industrial participation programme. Four teams embracing scientific and engineering personnel of eight concerns were given clearances for access to nuclear power technology and their first reports were termed " cautiously optimistic." A series of events in 1953 heightened the interest in nuclear power. The breeding principle was established at the Idaho reactor ; the submarine prototype was brought to substantial power and the construction of the U.S.S. " Nautilus " was well under way. The principle of the homogeneous reactor was tested successfully and, in February, 1953, its heat operated a 150kW generator. The Joint Congressional Committee held extended hearings on the development of nuclear power, hearings which marked the beginning of revision of the original Atomic Energy Act, of 1946. The Commission at these hearings laid down its basic policy for encouragement and support of a nuclear power programme for the United States.

Steady progress was made in improving health and safety standards, and the refinement of these procedures has given the Commission a safety record which has been widely commended. Isotopes and direct radiations found increasing uses in medical research and treatment. The Argonne Cancer Research Hospital was completed and began working and advances were made in the use of the isotope cobalt-60 for cancer treatment. Hundreds of field tests across the nation, using tracer amounts of the phosphorus isotope accumulated more accurate knowledge on the action of fertilisers than had been possible in the preceding half-century. The advances in nuclear research continued with the discovery of the elements 97 and 98—Berkelium and Californium—in 1950 ; the completion of the



**Erection of 235-ton reactor pressure vessel at the first American full-scale commercial nuclear power station at Shippingport, Pennsylvania**



**Artist's impression of 10MW commercial nuclear power station using the General Electric single-cycle boiling water reactor mounted inside the sphere**

Brookhaven "cosmotron" in January, 1952, when it achieved a 2300MeV beam, and the conception of a new principle which may make possible machines delivering up to 100,000MeV.

### 1954 to 1956

These developments ushered in the third and current phase of the U.S. programme: the three-fold programme of (1) international co-operation to extend the peaceful uses of atomic energy; (2) wider and more independent industrial participation in all phases of the programme, especially in the area of nuclear power development, and (3) intensifying the Commission's effort to make technical knowledge available so as to broaden the base for the special education and training of manpower and thus to speed the fulfilment of the first two objectives. This phase began on December 8, 1953, when President Eisenhower laid his "Atoms-for-Peace" proposals before the General Assembly of the United Nations. In the three years since that address, there has been almost unanimous approval from all over the world and much has been accomplished.

The International Atomic Energy Agency proposed in the President's United Nations speech is nearing reality. Its statute was approved by representatives of eighty-one nations that met at the United Nations last September, and, upon ratification by the requisite number of these nations, the agency will begin to operate. Since May, 1955, the United States has concluded thirty-nine bilateral agreements for co-operation in civil uses of atomic energy with thirty-seven nations, of which thirty-one already are in effect. Seven of these agreements are for assistance in nuclear power development.

The United States initiated the historic Conference on Peaceful Uses of Atomic Energy at Geneva in August, 1955. This conference marked the first wide international exchange of nuclear data in the "atomic" age and was one of the largest international scientific conferences ever held. The Commission, as part of its exhibit at the conference, arranged to fly a complete research reactor from Oak Ridge to Geneva where it was erected, operated throughout the conference, and later sold to the Swiss Government. Other American projects were launched to assist friendly nations in the development of peaceful atomic schemes. The International School of Nuclear Science and Engineering was established at the Argonne National Laboratory with co-operation from other universities. The school already has enrolled 163 post-graduate students from thirty-eight nations. At the Oak Ridge Institute of Nuclear Studies isotope techniques courses have been set aside for foreign nationals, and comprehensive technical libraries have been given to forty-four nations and three international organisations.

On February 22, 1956, the President approved a recommendation of the Commission and announced that 40,000 kg of uranium-235 would be allocated for civilian uses of atomic energy, half of which would be for fuelling power and research reactors in friendly foreign countries. This was followed on November 18 with the establishment of the charges to be made for this material and the prices the United States would pay for the special materials, principally plutonium, produced in reactors abroad fuelled with uranium obtained under the bilateral agreement programme. The President announced in June, 1955, that financial assistance on a matching basis would be given to nations seeking to establish nuclear research programmes and grants have been committed to four nations that have launched projects to build research reactors. The Atoms-for-Peace programme has continued to receive widespread approval abroad and has become an important interest of the foreign policy of the United States.

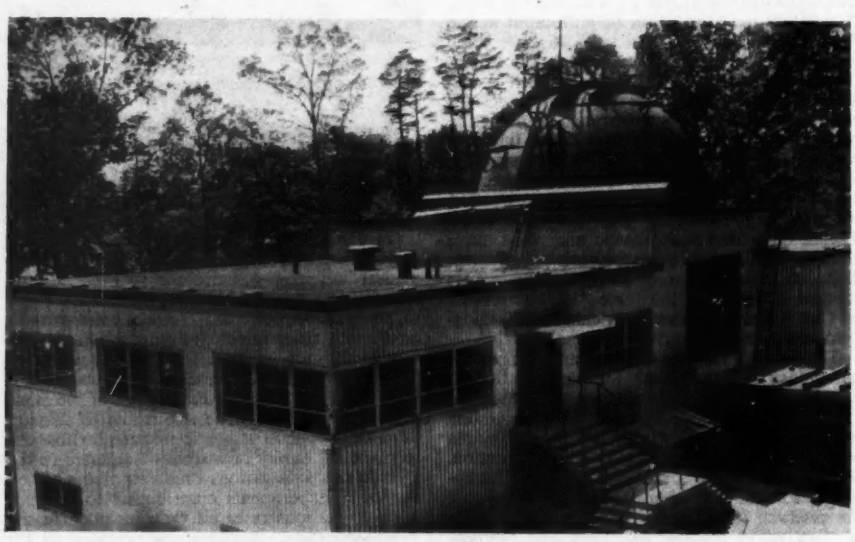
### The 1954 Atomic Energy Act

The international co-operation outlined became feasible only after the enactment on August 30, 1954, of the first complete revision of the original American atomic energy law. This revision also authorised the expansion of private participation in the national programme and laid the foundation for a competitive atomic energy industry operating under government regulation to protect the common defence and security and ensure public health and safety.

For the first time, the 1954 Atomic Energy Act authorised the private ownership of production facilities, including nuclear power plants and the licensing of special nuclear materials, principally fuel for power and research reactors, to private persons and corporations. It also provided a basis for the dissemination of classified information of industrial interest under an access permit programme. More than 1000 persons and firms have by now received access permits. The Commission's five-year 250 million dollar experimental civilian power programme, announced in 1954, has moved ahead steadily to the point where the first full-scale nuclear power station—the 60MW capacity station at Shippingport, near Pittsburgh, Pennsylvania—and several smaller-scale power reactor experiments, are nearing completion and are scheduled to begin operation this year. The basic experimental programme, which included five reactor designs, has now been enlarged to include four new reactor concepts which are to be carried at least to the pilot plant stage.

In January, 1955, the Commission established its "Power Demonstration Reactor Programme" to encourage American industry to develop, build and operate experimental nuclear power reactors with some assistance from the Government. The aim of the programme is to bring private resources into the development of engineering information on the performance of nuclear power reactors and to advance the time when nuclear power will become economically competitive. Ten nuclear power stations, with a combined electrical capacity of more than 400MW, have been proposed under this programme. In addition, American industry is proposing to construct entirely with its own funds, seven nuclear power stations having an estimated generating capacity of about 900MW, according to announcements by the companies involved. Their preliminary estimates indicate that the investment in these stations would run between 250 million dollars and 300 million dollars.

The ship propulsion programme has moved ahead rapidly with seventeen naval vessels—fifteen submarines, one aircraft carrier and a guided missile vessel—now being built or planned. The U.S.S. "Nautilus" has steamed more than 50,000 miles since she was first propelled by nuclear power on her maiden trip on January 21, 1954. Congress has authorised a 42,000,000 dollar nuclear powered cargo ship which is being designed and built as a joint project of the A.E.C. and the U.S. Maritime Commission. The programme for nuclear propulsion of military aircraft has moved ahead steadily. The experimental "package" nuclear power plant being constructed by the U.S. Army at



**1925kW U.S. Army package power reactor generating station using enriched uranium fuel. The station is shown approaching completion at Fort Belvoir, Virginia**

Fort Belvoir, Virginia, is expected to be in operation this summer. Meanwhile, five non-governmental or private research reactors have been built, two more are under construction and nineteen more are planned.

The 1954 Act also made it possible for American industry to compete in the world nuclear reactor market. American firms have signed or are negotiating a score of contracts for the design, manufacture and installation of research reactors abroad, and two nations—Belgium and Italy—have contracted for a power reactor to be built by American firms. American and Foreign Power, Incorporated, has announced that it will install 10MW nuclear power plants in three Latin American nations. The first reactor export licence was recently issued in connection with the sale of a research reactor to Japan.

### Declassification of Information

After the conference on peaceful uses of atomic energy in 1955, the Commission executed an accelerated review of 30,000 technical reports which were believed to be of interest to industry. As a result, approximately 10,000 were declassified and another third were down-graded to the "Confidential" category. This action was followed by an expansion of the Commission's programme for the publication of bibliographies and of the more useful reports. On December 12, 1956, in co-operation with the United Kingdom and Canada, under the tripartite declassification programme developed during World War II, authorisation was announced for the declassification of another large volume of technical information that will compare with the amount of data reported at the 1955 international conference at Geneva. This action also makes it possible for commercial publishers to prepare comprehensive texts and other study materials to speed the education and training of nuclear scientists and engineers. As further aids in breaking through the current manpower shortage, the Commission has doubled the capacity of the Oak Ridge reactor school, established new fellowships and supported refresher programmes for college and high school teachers.

### Nuclear Research and Development

The 1954 Act did not alter the Commission's primary responsibility to make the maximum contribution to the common defence and security. To this end, the current programme has attained its goal of geographic dispersion of vital components of the weapon "assembly line." The American nuclear arsenal is being expanded in number and variety, including weapons primarily designed for defence purposes. In 1956, at the Eniwetok Proving Ground, news correspondents witnessed an air drop of a device in the "megaton" range. During this series, as a new development, there were tested high-yield weapons having greatly reduced radiological hazard due to fall-out.

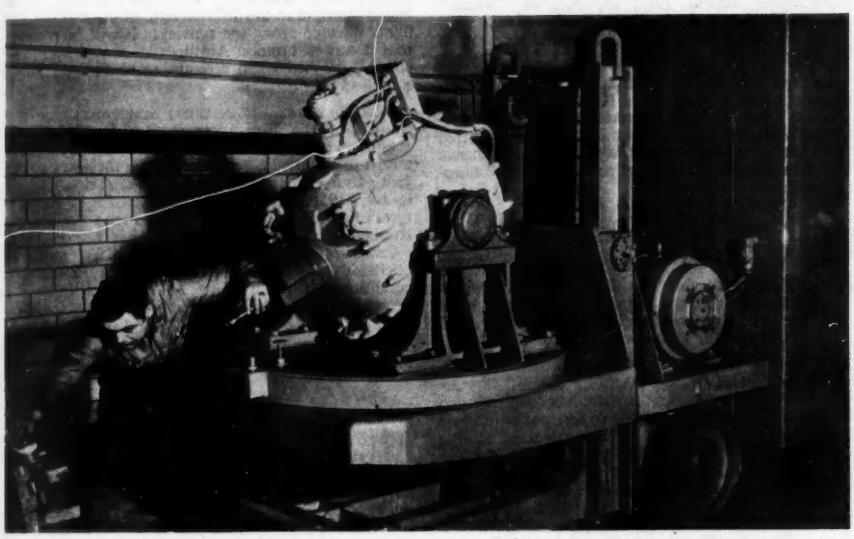
The production of fissionable material has reached a record as new manufacturing and processing units have now gone into operation. In the raw materials field, the United States has become the world's greatest producer of uranium, with more than 1000 mines now operating. The uranium concentrate production in December, 1956, was at the rate of more than 8000 tons per year—double the rate at the beginning of the year. The domestic uranium reserves were estimated at 60,000,000 tons in comparison with 1,000,000 tons in 1948.

Other aspects of the nuclear programme also have made commensurate progress. The number of isotope users has grown to 3624 and industrial savings achieved through the application of isotopes are estimated at several hundred million dollars annually. More than 1300 medical institutions and physicians are using radioactive isotopes. In certain kinds of diagnosis and therapy, the use of the tracer atoms has become routine. In research, these isotopes are helping to extend the areas of medical knowledge, and the first reactor designed primarily for medical research is under construction at the Brookhaven National Laboratory.

In basic research conducted during this period, three more new elements have been identified, namely, 99, 100 and 101, named Einsteinium, Fermium and Mendelevium. Great strides have also been made in identifying sub-atomic particles of the nucleus, thus opening the way for further research into the basic structure of matter. In research sponsored by the Commission, the existence of the long-sought neutrino, tentatively identified in 1953, was proved in 1956 as was that of the anti-neutron. These events were preceded by the discovery in 1955 of the anti-proton.

The Commission recently announced a co-ordinated programme of research on the control of the fusion process by which the nuclei of light elements are combined, in an effort to achieve the practical, controlled release of energy through thermo-nuclear reactions.

The Commission now requires about 2000 million dollars a year to operate this far-flung and complex programme. The capital investment during the ten years of operation has grown, before depreciation, from an estimated 1200 million dollars in 1947 to nearly 7000 million dollars as at the end of 1956. All segments of American industry participate in the Commission's programme. The main contractors include some of the nation's largest concerns. At the same time, under a sub-contracting policy adopted in 1951, the amount of work done by small business has grown steadily. In a report made in August, 1956, by the Senate Small Business Committee, the Commission was commended for the "aggressive and imaginative" execution of this policy under which "the share of the A.E.C. subcontract dollars going to small business has risen from 26·7 per cent in 1951 to 47·6 per cent in the first half of 1956." The direct employees of the Commission were 4746 in 1949 and are 6636 to-day.



**The Babcock and Wilcox "Isoscope" being used in the radiography of a steel casting—an industrial application of radioactive isotopes developed by the A.E.C.**

### Nuclear Power Stations

While it is generally agreed in American atomic energy circles that the A.E.C. has done an outstanding job in nuclear research and development, there has been considerable recent criticism concerning the slow progress of the American civilian atomic power stations. These feelings became all the more pronounced after the opening of Great Britain's Calder Hall station and the subsequent symposium in London on its design and construction.

Possibly in answer to some of these criticisms, Mr. Lewis L. Strauss, the Chairman of the Atomic Energy Commission, recently announced that the Commission is extending a third invitation, under its Power Demonstration Reactor Programme, for proposals to develop, design, construct and operate nuclear power stations. The invitation is extended to provide a continuing programme of assistance by the Commission to American industry, both private and public, in using its resources for the development of engineering information on the performance of nuclear power reactors and to advance the time when nuclear power will become economically competitive. In announcing the invitation, Mr. Strauss reaffirmed that it is the policy of the Commission to promote the construction and operation of demonstration nuclear power stations as justified by their technological status under the best arrangement which can be obtained.

The present invitation differs in several important respects from the two earlier invitations extended by the Commission. It calls for the submission of proposals as soon as possible. The proposals will be considered by the Commission as they are received, within the limit of funds available. No date has been established for the receipt of proposals, the only time factor being a stipulation that the construction of the plants proposed will be completed by June 30, 1962. No limitation has been placed on the kind or size of nuclear power plants which may be proposed, except that they should make a significant contribution toward the achievement of the commercial utilisation of nuclear power. The research and development assistance requested in the proposals must be well defined and for fixed dollar amounts.

There are now being developed, in large-scale demonstration projects, the pressurised water reactor, the boiling water reactor, the sodium-graphite reactor and the fast breeder reactor. The technology of two other designs of reactors is such that construction of additional large-scale demonstration projects of these designs within the specified time schedule is warranted and desirable. These designs are: (*a*) The natural-uranium-fuelled, heavy-water-moderated reactor, and (*b*) the fluid-fuel reactor system based on aqueous solutions or slurries of uranium or of uranium and thorium-bearing materials. Other designs of reactors will be specified by the Commission for construction as technological progress appears to warrant such announcements. If industry does not submit acceptable proposals for reactor plants of the types considered ready for full-scale construction, the Commission will request additional funds to initiate such projects under complete Government financing.

The assistance granted by the A.E.C. in these projects will be limited to research and development. The proposers will be required to provide funds for construction. Under the previous arrangements the Commission considered the financing of all or part of the nuclear portion of the proposed plants, retaining title to the parts it financed. A new form of assistance has been offered in the present invitation: the A.E.C. will consider requests for the loan of heavy water without charge for up to five years of operation of any nuclear power station designed to be fuelled with normal uranium. This provision is in addition to a waiver of established Commission charges for the use of source and special nuclear materials under specified conditions.

# Personal and Business

## Appointments

MR. N. A. GASS has been appointed chairman of the British Petroleum Company, Ltd.

MR. B. L. SNOW, sales manager, has been appointed a director of George Mann and Co., Ltd.

MR. DAVID MARTIN JINKS has been appointed a director of Cleco Electric Industries, Ltd.

MR. G. ANTHONY HEPWORTH has been appointed a director of Associated Engineering (Sales), Ltd.

MR. A. R. W. LOW has been appointed a director of Dowsett Holdings, Ltd., and has been elected deputy chairman.

MR. HUGH R. BYERS, special director and sales manager, has been appointed a director of William Beardmore and Co., Ltd.

WING COMMANDER E. G. MONK has been appointed regional manager, United Kingdom, of the Bendix Aviation Corporation of the U.S.A.

THE ADMIRALTY announces that on March 31, Captain A. H. Wallis, R.N., will succeed Captain A. W. Clarke, R.N., as Chief of Naval Information.

MR. G. W. HALL, a vice-chairman and managing director of the Fairey Aviation Company, Ltd., has been appointed acting chairman following the death of Mr. Roland T. Outen.

MR. F. S. MOCKFORD, commercial manager of Marconi's Wireless Telegraph Company, Ltd., has been elected chairman of the Radio Communication and Electronic Engineering Association.

MR. C. J. HOWARD had been appointed managing director of John Thompson Water Tube Boilers, Ltd., in succession to Mr. W. R. Edwards, M.I.Mech.E., who has retired after fifty years' service with the company.

THE BRITISH TRANSPORT COMMISSION announces that Mr. J. E. B. Jefferson has been appointed senior assistant in the finance department, and Mr. C. A. Pass has been appointed assistant (motive power), British Railways central staff.

MR. H. MORLEY, work study officer to the United Steel Companies, Ltd., has been appointed works manager (services) of Samuel Fox and Co., Ltd., Stocksbridge. Mr. J. H. D. Kerse will succeed Mr. Morley as work study officer from April 1.

SAMUEL FOX AND CO., Ltd., has announced the following appointments in connection with the opening of its new combined bar and rod mill: Mr. P. Thompson, manager of the bar and rod mill; Mr. A. E. Hanselman, assistant manager (rolling); Mr. L. Long, assistant manager (warehouse and treatment); Mr. A. Crossley, manager (steel treatment department); Mr. C. Brooks, assistant manager (No. 1 melting shop).

HEAD WRIGHTSON AND CO., Ltd., has announced the following appointments as directors of its newly-formed subsidiary companies: Head Wrightson Teesdale, Ltd., Mr. R. H. Sturges (managing) and Mr. R. Purnell; Head Wrightson Stockton Forge, Ltd., Mr. J. W. Wardell (managing) and Mr. R. B. W. Bolland; Head Wrightson Iron Foundries, Ltd., Mr. N. Addison; Head Wrightson Iron and Steel Works Engineering, Ltd., Mr. T. H. Stayman.

## Business Announcements

HOLDEN AND BROOKE, Ltd., states that its Birmingham office has moved to 8, Waterloo Street, Birmingham, 2 (telephone, Midland 3953).

MENTMORE MANUFACTURING COMPANY, Ltd., states that its plastics division has moved to Six Hills Way, Stevenage, Herts (telephone, Stevenage 1701).

COMPOFLEX COMPANY, Ltd., states that it has acquired the entire share capitals of Rollo Hardy and Co., Ltd., and Tube Making Machines, Ltd.

MIDLAND SILICONES, Ltd., states that its N.E. area sales office has moved to 5/7, New York Road, Leeds, 2 (telephone, Leeds 26768). The area sales manager is Mr. R. Nattrass.

MR. F. W. MCCOMBIE, managing director of Megator Pumps and Compressors, Ltd., is to make a four-week tour of South Africa and Rhodesia. He will leave, by air, to-morrow.

THE CENTRAL ELECTRICITY AUTHORITY has announced the retirement at the end of February of Mr. G. A. Vowles, M.I.Mech.E., M.I.E.E., controller of the Authority's Yorkshire division.

BRITISH HYDROCARBON CHEMICALS, Ltd., states that its two new plants for the production of ethylene and of ethanol (industrial alcohol) have been brought into commercial operation.

THE DECCA NAVIGATOR COMPANY, Ltd., states that it has acquired the rights for the United Kingdom and certain other countries of the electronic self-steering device, the Arkas automatic pilot. This operates with either magnetic or gyro compass and incorporates an automatic counter rudder which ensures precise course-holding with reduced helm movement, and also permanent helm, which enables weather helm to be applied.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that as from February 25, the address of its Southampton branch office will be 16/17, Vincent's Walk, Southampton (telephone, Southampton 26176/7).

THE UNIVERSAL ASBESTOS MANUFACTURING COMPANY, Ltd., has announced the formation of U.A.M. Plastics, Ltd., a wholly-owned subsidiary which will manufacture glass fibre reinforced plastics materials based on polyester resins.

T. H. AND J. DANIELS, Ltd., of Stroud, Gloucestershire, states that it has acquired the whole of the issued share capital of British Boiler Accessories, Ltd. The association with Schiff and Stern, Ltd., of British Boiler Accessories, Ltd., will be continued.

BROOK MOTORS, Ltd., states that the formal notice published in the *London Gazette*, relating to Brook Motors, Ltd. (in voluntary liquidation), refers to the former subsidiary company of that name, the undertaking of which was acquired and is being carried on by the present Brook Motors, Ltd.

HATTERSLEY BROTHERS, Ltd., Mexborough, Yorkshire, states that it has taken over the business of Autocontrol Boilers, Ltd., suppliers of "Vesta" "Vertex" and "Vulcan" gas-fired boilers. Mr. T. E. Norvell has been appointed general manager of the gas division of Hattersley Brothers, Ltd.

G. A. PLATON, Ltd., 323A, Whitehorse Road, Croydon, Surrey, states that it has been formed to provide a technical sales service to industries concerned with the handling of fluids. It has acquired from the patentees and Ultrasonics, Ltd., exclusive rights to manufacture and sell the "Flostat" automatic flow controller.

## Contracts

THE ENGLISH ELECTRIC COMPANY, Ltd., has received an order for "Canberra" aircraft worth more than £20,000,000 for delivery to the Indian Air Force. They comprise fifty-four Mk. VIII bombers, eight Mk. VII photographic reconnaissance aircraft, and six Mk. IV trainers.

BRUSH ABOE (CANADA), Ltd., a subsidiary of the Brush Group of Great Britain, has been awarded a contract valued at £350,000 for power station machinery for a sewage purification plant serving Toronto City, at Humber Valley. The National Gas and Oil Engine Company, Ltd., will supply the main machinery, valued at £167,000, comprising four "B2AG8" eight-cylinder, spark-ignited gas engines of 900 b.h.p. at 336 r.p.m., each direct-coupled to a Rootes-Connersville rotary blower through a Barclay-Curle fluid coupling. Provision will be made for future installation of two 620kW, 60 c/s alternators in tandem with the blowers of two sets. Noise and vibration will be minimised by spring-loaded machine foundations and flexible connections for all pipelines; sewage gas or natural gas will be used as fuel. The purification plant will have a d.w.f. of 28·75 m.g.d.

THE CENTRAL ELECTRICITY AUTHORITY has awarded a £750,000 contract for the erection of three cooling towers which are believed will be the biggest in the world, to the Mitchell Construction Company of Peterborough. They will serve High Marnham power station, in Nottinghamshire, which will have an ultimate installation of five 200MW turbo-alternator sets. Provision is made in the contract for its possible extension to include the construction of two further towers. The towers will reach a height of 349ft above pond-bottom and will have a diameter of about 266ft at base. Each will have a maximum capacity of 6 m.g. an hour, circulated by a 6ft 3in diameter concrete pipe connected to a centre feed structure. The cooling system will use river water only in a closed circuit. Water will be cooled from 87 deg. to 70 deg. Fah. during atmospheric conditions of 55 deg. Fah. dry bulb and 70 deg. Fah. humidity. The towers will be built on marl and no piling will be necessary. They will be supported on 18in diameter diagonal columns. The cooling tower ponds will be 270ft in diameter, with a depth of 7ft, and each will hold 2·5 m.g. A number of new techniques are to be used, including the provision of a new type of climbing scaffold developed by the company primarily for cooling tower construction. The first tower is due to be finished by February 1, 1959, and the whole contract is scheduled for completion by September, 1960. Messrs. Freeman, Fox and Partners are the consulting engineers for the High Marnham power station.

## Miscellanea

MANCHESTER CITY ENGINEER'S REPORT.—We have received a copy of the annual report for the year ended March 31, 1956, of the City Surveyor and Engineer's Department of Manchester. Progress in housing and street works and in main drainage is recorded. Much of the highway repair work carried out involved placing mechanically a "skim" coat of bitumen or asphalt carpet on sett-paved carriageways. Work was also in progress at the city's airport, to strengthen the main runway.

CIVIL ENGINEERING AS A CAREER.—The Institution of Civil Engineers has produced a four-page pamphlet which gives some helpful particulars as to the ways of entering the civil engineering profession. It emphasises also the opportunities throughout the world which are open to civil engineers. The intention is that the pamphlet shall be issued to schools and circulated at appropriate engineering exhibitions. Copies of it are available from the Institution of Civil Engineers, Great George Street, London, S.W.1.

REFLECTIVE SIGNS.—To assist pilots and drivers in locating themselves upon the taxi-ways and runways of London Airport, 288 reflective position indicators have now been mounted on the grass verges. Each indicator carries the number of one of the 100 blocks into which the area has been divided. The markers consist of 4ft by 2ft panels of silver "Scotchlite" bearing black numbers: the reflecting background becomes bright in the diffused light of aircraft landing lights directed along the runway. It will be recalled that it was at London Airport that a Vickers "Viscount" crashed when attempting to take-off along a taxi-way.

AGRICULTURAL ENGINEERING SCHOLARSHIPS.—The council of the Institution of British Agricultural Engineers is again able to offer three scholarships for award to candidates who are eligible for entry to the year's course of study leading to the final examination in July, 1958, for the National Diploma in Agricultural Engineering. The scholarships are: the Dunlop Rubber Company scholarship, value £250; *Farm Mechanization* scholarship, value £100, and the Shell-Mex and B.P. scholarship, value £250. The conditions of award may be obtained from the Secretary of the Institution of British Agricultural Engineers, 6, Buckingham Gate, London, S.W.1. Preliminary inquiries should be made as soon as possible; the closing date for receiving completed applications is May 1, 1957.

B.I.S.R.A. OPEN DAYS.—The British Iron and Steel Research Association will hold two open days at the Sketty Hall, Swansea, laboratories, on Thursday and Friday, June 20 and 21, for representatives of B.I.S.R.A. member firms and users of steel sheet and strip throughout industry. The Sketty Hall laboratories are devoted to research into problems concerning steel coatings and methods of surface preparation conducted by the Association's mechanical working division. The open days will provide an opportunity for showing improvements in existing coating methods which have been achieved, together with developments in the use of new coating materials. Demonstrations will be given on the recently installed experimental line for the production of PVC-bonded steel strip, and on the differential roller tinning pilot plant now being built. Other projects, including the continuous lacquering of steel strip, the use of iron-zinc and iron-tin alloys, and research into methods of gaseous deposition of metallic coatings, will also be displayed and demonstrated.

PIPELINE INDUSTRIES GUILD.—A newly formed society of those engaged in or associated with design, laying, maintenance, and so on, of pipelines recently held its inaugural meeting in London. A steering committee set up at the founding general meeting in November last year reported its recommendations for the title of the organisation, the constitution and rules, and finance. The meeting unanimously adopted the title of the Pipeline Industries Guild. As finally agreed, the objects of this Guild are: to promote, foster and develop the science and practice of pipeline design, construction, operation and ancillary processes and techniques; to enable all persons engaged in pipeline construction, operation and allied industries to meet and to correspond; to exchange technical ideas, to promote research and development upon pertinent subjects and join other bodies in doing so; to organise conferences and functions, and to establish, administer and contribute to educational and other funds. Membership is divided into two classes, i.e. individuals and corporate members, such as companies and other bodies, who shall nominate their representatives. Mr. C. C. Bates is the honorary secretary, and forms of application for membership are available from him at 7, Iddesleigh House, Caxton Street, London, S.W.1.

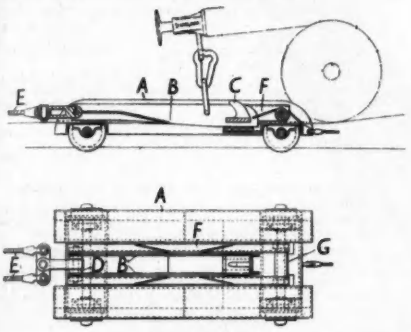
# British Patent Specifications

*When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.*

## RAILWAY ENGINEERING

**766,505.** January 25, 1955.—APPARATUS FOR HAULING WAGONS, Ross Engineers, Ltd., 11, Walpole Road, Surbiton, Surrey; and Lycurgus William Barrow, of the Company's address.

The invention relates to bogie carriages for hauling or controlling vehicles and more particularly for controlling the movement of railway wagons either on the level or on graduated tracks, and where in the latter case the wagons require to be hauled up or lowered down a grade under control. Referring to the drawing, *A* is the main frame of the bogie carriage which is mounted on a pair of wheel axles. The rail track for the bogie carriage is of narrow gauge and is disposed slightly below the main rail track for the wagons which the bogie carriage controls. The bogie carriage has a pair of parallel drawbars *B*, which are spaced apart as shown and are provided at the rear end with a central hook *C*, while at their forward end these drawbars are attached by a pivot pin *D* to a connecting piece attached to a pair of hauling or control ropes *E*. The drawbars are attached to the bogie carriage by a pair of parallel connecting arms or levers *F*, which at their forward



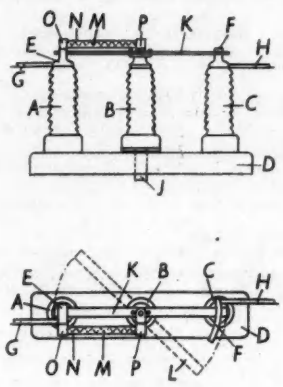

No. 766,505

end are pivotally connected to the forward ends of the drawbars by the pivot pin *D* and which at the rear end are pivotally connected to the chassis by the pivot pin *G*. The space between the drawbars *B* of the bogie carriage is sufficient to allow the depending coupling chain of a wagon to hang freely between them so that when the bogie carriage is pulled forward from under the wagon by its drawbars the latter will be in the position shown in the drawing, and the hook will thus be drawn into engagement with the bottom link of the coupling chain. As the hauling force begins to take up the load imposed by the wagon the drawbars will lift into position so that the hauling ropes *E* and drawbars *B* of the bogie carriage are substantially in alignment with the coupling chain and drawbar of the wagon, the connecting arms *F* swinging upwards about the pivot *G*. This enables the bogie carriage drawbar to give a direct pull on the railway wagon drawbar and thus obviates any danger of damage to the wagon axle and allows the spring or cushion device of the wagon drawbar to perform its normal function of damping down snatch. Furthermore, the arrangement enables the hauling force to be applied in a direct line with the wagon drawbar without any danger of the bogie being lifted from its rail track, as no uplift is imparted to the bogie through the connecting arms.—*January* 23, 1957.

## ELECTRICAL ENGINEERING

**766,699.** July 2, 1954.—ELECTRIC ISOLATING SWITCHES, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventors: Charles Fogden Humphreys and Archibald Hayward Pollard.*)

The invention relates to electric isolating switches of the air-break kind employed for effecting isolation between power transformers and high-voltage transmission lines and the like. It is essentially concerned with isolating switches comprising relatively removable contacts operating in free air. The isolating switch shown in the drawing comprises three insulating posts *A*, *B* and *C*, mounted on a base structure *D*. The two outer posts *A* and *C* carry fixed contacts *E* and *F*, connected with the line conductors *G* and *H*, to be isolated by the switch. The centre post *B* is mounted on a rotatable vertical shaft *J* and carries a contact blade *K* extending between the two fixed contacts. Rotation of the shaft *J* moves the blade *K* into the position shown at *L* to disconnect the ends of the blade from the two fixed contacts. In accordance with the invention a resistance *M* is connected between one of the fixed contacts and the centre point of the blade. As shown, the resistance is mounted within an insulating tube *N*, one end of which is supported from the contact *E* by means of a metal bracket *O*, and which also serves to connect the adjacent end of the resistance *M* with the contact. The other end of the tube is carried by a metal bracket *P*, having a pivotal support on the blade *K*. The bracket *P* also connects the adjacent end of the resistance with the blade. The fixed contact *F* is preferably curved so that on movement of the blade from the illustrated closed position it will not dis-

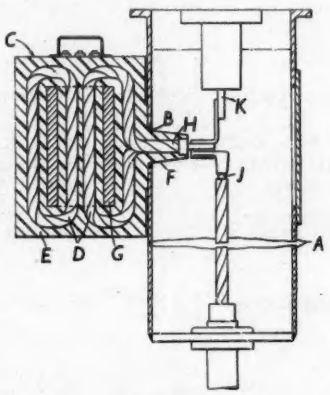



No. 766,699

engage the contact *F* until after disengaging the fixed contact *E*. In the operation of this arrangement the opening movement of the blade *K* will thus first open the circuit at the contact *E* so as to insert the resistance *M* and reduce the current in the line conductors *G* and *H* and thereafter the current in the resistance will be interrupted by opening of the contacts *K* and *F*. It will be understood that the invention is generally applicable to isolating switches of all forms as well as to the particular type described.—*January* 23, 1957.

**766,450.** March 19, 1954.—HIGH-VOLTAGE ELECTRIC SWITCHGEAR, A. Reyrolle and Co., Ltd., of Hebburn, County Durham. (*Inventor: John Christie.*)

The invention relates to metal-clad high-voltage electric switchgear, including a cable termination chamber. In the drawing a metal terminal chamber *A* associated with a high-voltage circuit breaker is provided with an aperture *B* in its wall, into which is plugged a moulded current transformer *C*, whose primary winding *D* is wholly embedded in a moulded insulating block *E* made from low moulding pressure synthetic resin. The terminal insulation in this particular construction for the primary winding is



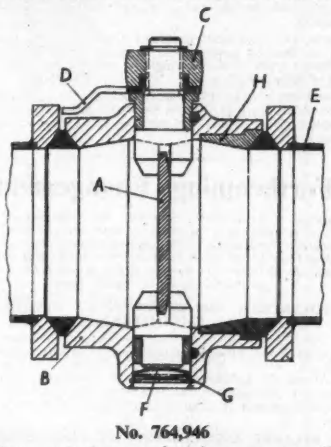

No. 766,450

in the form of a projecting insulating plug bushing *F*, which is moulded integrally with the insulation block *E*. The secondary winding and magnetic core *G* of the transformer are also embedded in the moulded block, although this is not essential. The outside of the block may be sprayed with metal or otherwise covered with an earthed metallic casing. The current transformer *C* is plugged into the aperture *B* in the terminal chamber *A*, and its primary winding leads *H* are connected respectively to the cable end *J* and the throughfare bushing conductor *K*. In a three-phase system the current transformer may be formed as a composite three-phase moulded unit or alternatively three separate single-phase units can be employed. A cable terminal chamber carrying a trip coil is also described in the specification.—*January* 23, 1957.

## INTERNAL COMBUSTION ENGINES

**764,946.** February 28, 1955.—ENGINE BRAKES, Zahnradfabrik Friedrichshafen Aktiengesellschaft, Friedrichshafen on the Bodensee, Germany.

The invention relates to an engine brake for an internal combustion engine. A disc-shaped exhaust brake valve within the exhaust pipe is arranged to close the pipe for engine braking. As the drawing shows, the exhaust brake valve *A* is rotatably mounted in the housing *B* between trunnions. The valve is operated by a lever *C*. A stop lever *D* limits the rotation of the valve by abutting against a flange connected to the exhaust gas pipe *E*. Bores to accommodate the bearing bushes are provided in the housing, the bearing bushes being detachably fastened in the housing by pins as shown. The disc-shaped brake valve has wedge-shaped incisions which register in machined slots in the trunnions. The lower trun-

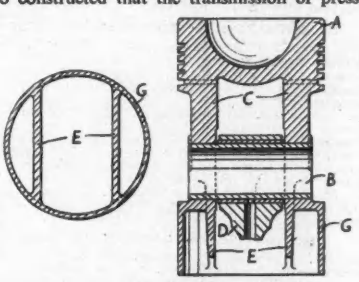



No. 764,946

nion bears at its lower end against a concave disc *F*, which, in turn, bears against a further resilient disc *G* corrugated around its edge portion, the two discs being held in the bore by a spring ring. The disc *G* imparts a springing action for the upper disc in the direction of its axis of rotation, and, due to the enlarged heat-dissipating surface formed by the corrugations around its edge, has a cooling action so that the disc *F* does not overheat. The interior of the housing *B* is widened in relation to the inside diameter of the exhaust gas pipe *E* and merges at the ends into the inside diameter of the pipe. An annular insert *H* at one end of the housing enables the disc *A* to be dismantled from the housing. Packing rings are inserted between the housing *B* and the flanges.—*January* 2, 1957.

**767,328.** July 22, 1954.—PISTONS OF COMPRESSION IGNITION ENGINES, L. Gardner and Sons, Ltd., Barton Hall Engine Works, Patricroft, near Manchester. (*Inventor: Joseph Hugh Stott Gardner.*)

The object of the present invention is to provide improved means for facilitating the transmission of heat from the lower portion of the piston surrounding the gudgeon pin and gudgeon pin bearing to the relatively cool cylinder walls and to the air and oil within the engine. The piston shown in the drawing is so constructed that the transmission of pressure




No. 767,328

from the piston crown *A* to the gudgeon pin *B* is effected through the skirt around the piston crown to two straight vertical walls *C* extending across the piston at the opposite sides of the gudgeon pin bearing in the eye of the connecting-rod *D*, the walls coming as close together as permitted by the length of the bearing. In accordance with the invention, there are weblike extensions *E* of the vertical walls *C*, coming below the gudgeon pin bearings and merging at their sides into the piston skirt below the gudgeon pin. Such weblike extensions may each have a thickness of from one-two hundred and twenty-fifth to one fortieth of the ouside diameter of the piston and may have a minimum length below the gudgeon pin axis of three tenths of the outside diameter of the piston.—*January* 30, 1957.

## Catalogues and Brochures

THOMAS MERCER, Ltd., Eywood Road, St. Albans. Leaflet giving details of developments and additions to the "Mercer" range of dial measuring equipment.

SIMON-CARVES, Ltd., Cheadle Heath, Stockport.—Illustrated brochure giving details of some of the coke ovens and steel works plant erected by this company in India.

HALL HARDING, Ltd., Stourton House, Dacre Street, London, S.W.1.—Booklet describing the "Ajax" power printer, designed for use where high output is necessary.

LANCASHIRE DYNAMO AND CRYPTO, Ltd., Trafford Park, Manchester, 17. Illustrated brochure dealing with fractional horsepower motors 0·05 h.p. to 0·95 h.p.

BLAW KNOX, Ltd., 90–94, Brompton Road, London, S.W.3.—Leaflet describing "Auto-Airflow" elevating and conveying equipment for powders, fine granular and flaked materials.

MATTHEWS AND YATES, Ltd., Cyclone Works, Swinton, Manchester. Illustrated leaflet describing "Turbo-Cyclone" P.V.C. fans for chemical fumes, corrosive gases and laboratory ventilation.

BROWN AND TAWSE PLANT, Ltd., West Gorton, Manchester, 12. Illustrated catalogues giving details of the "Hydrocon" Mark IV, 3-ton mobile crane, "Pluto" pneumatic tools and air accessories.

REVOL, Ltd., Exchange Buildings, Quayside, Newcastle upon Tyne, 1.—Booklet covering the manufacture and maintenance of different types of belting, together with general hints on the fitting of belts.

JAMES NEILL AND CO. (SHEFFIELD), Ltd., Napier Street, Sheffield, 11.—Booklet No. P.M. 162/56, entitled "Small Magnets are so Versatile," giving details of a range of small magnets and some of their applications.

## Forthcoming Engagements

*Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the* TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

### ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

*Wed., Feb.* 27.—BRIGHTON, HOVE AND DISTRICT BRANCH: New Imperial Hotel, First Avenue, Hove, "Cathode Ray Tubes," 7.30 p.m.

*Fri., March* 1.—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, 2, "Trends of Developments of Electric Traction," J. H. Cansdale, 7.30 p.m.

### BELFAST ASSOCIATION OF ENGINEERS

*Wed., Feb.* 27.—College of Technology, Belfast, "The Application and Maintenance of Centrifugal Pumps," A. J. Clements, 7.30 p.m.

### BRITISH INSTITUTION OF RADIO ENGINEERS

*To-day, Feb.* 22.—SCOTTISH SECTION: Department of Natural Philosophy, University of Edinburgh, Edinburgh, Joint Meeting with the Royal Statistical Society, "The Field Evaluation Trials of Electronic Equipment," H. Holmes; and "The Electronic Manipulation of Digits Applied to Statistics," J. Kyles, 7 p.m.

*Wed., Feb.* 27.—London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Some Applications of Nucleonics in Medicine," E. W. Pulsford, 6.30 p.m.

### BRITISH INTERPLANETARY SOCIETY

*Sat., March* 2.—Caxton Hall, Caxton Street, London, S.W.1, "The Design and Application of Solid Propellant Rocket Motors," E. T. B. Smith, 6 p.m.

### CEMENT AND CONCRETE ASSOCIATION

*Mon., Feb.* 25.—Cambridgeshire Technical College, Collier Road, Cambridge, "Weathering and Deterioration of Concrete Renderings," C. Hobbs, 7.30 p.m.

*Wed., Feb.* 27.—Harris Institute, Corporation Street, Preston, "Surface Finishes of Concrete," J. G. Wilson, 7 p.m.

*Thurs., Feb.* 28.—Technical College, Chesterfield Road South, Mansfield, "Recent Developments in Prestressed Concrete," S. C. C. Bate, 7.15 p.m.

### CHEMICAL SOCIETY

*Thurs., Feb.* 28.—Burlington House, Piccadilly, London, W.1, "Application of Acidity Functions to the Mechanisms of Acid Catalyzed Reactions," F. A. Long, 7.30 p.m.

### HULL CHEMICAL AND ENGINEERING SOCIETY

*Tues., Feb.* 26.—Hull Church Institute, Hull, "Manufacture of Antibiotics," D. Daniel, 7.30 p.m.

### ILLUMINATING ENGINEERING SOCIETY

*To-day, Feb.* 22.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, Annual General Meeting, 6 p.m. ★ MANCHESTER CENTRE: N.W. Electricity Board, Town Hall, Manchester, 2, Exhibition of Domestic Lighting Equipment.

*Mon., Feb.* 25.—LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, 1, Forum, "Street Lighting—Whither?" B. Waring, L. A. Doxey, R. R. Burrow and L. Clark, 6.15 p.m. ★ LEICESTER CENTRE: E. Midlands Electricity Board, Charles Street, Leicester, "Lighting for Photography," R. W. Unwin, 6 p.m.

*Tues., Feb.* 26.—Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Open Space Lighting," H. F. Stephenson and M. W. Peirce, 6 p.m.

### INCORPORATED PLANT ENGINEERS

*Mon., Feb.* 25.—W. AND E. YORKSHIRE BRANCH: Leeds University, Leeds, "Fuel and the Future," A. L. Roberts, 7.30 p.m.

*Tues., Feb.* 26.—Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, "Annual General Meeting, 7 p.m. ★ S. WALES BRANCH: S. Wales Engineers' Institute, Park Place, Cardiff, "Heating and Ventilating in Modern Works," 7.15 p.m.

*Thurs., Feb.* 28.—SHEFFIELD AND DISTRICT BRANCH: Grand Hotel, Sheffield, "An Interpretation of the Clean Air Bill," 7.30 p.m. ★ SOUTHERN BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 7.30 p.m.

### INSTITUTE OF BRITISH FOUNDRYMEN

*Wed., Feb.* 27.—LONDON BRANCH: Constitutional Club, Northumberland Avenue, London, W.C.2, "Methods Engineering, with Emphasis on the Flow Production Applied to Fettling-Shop Control," F. Gaiger and R. Hancox, 7.30 p.m.

### INSTITUTE OF FUEL

*Wed., Feb.* 27.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Measurements of the Size of Droplets from Convergent-Divergent Nozzles Used in Oil Burners for Steel Furnaces," E. J. Burton and J. R. Joyce; and "Flow and Disintegration of Thin Sheets of Visco-Elastic Fuels," N. Dombrowski, P. Eisenklam and R. P. Fraser, 5.30 p.m.

### INSTITUTE OF MARINE ENGINEERS

*Mon., Feb.* 25.—W. OF ENGLAND SECTION: Grand Hotel, Bristol, Annual General Meeting, followed by two films, "Forward Together," and "The Diesel Generator as a Composite Heat and Power Unit," 7 p.m.

*Tues., Feb.* 26.—SOUTHERN JOINT BRANCH I.N.A.: College of Technology, Portsmouth, "Welded Aluminium Ships' Structures," E. C. B. Corlett and J. Leathard, 7.30 p.m.

*Wed., Feb.* 27.—S. WALES SECTION: Swansea Technical College, Mount Pleasant, Swansea, "Diesel Hydraulic Propulsion," F. J. Mayor, 7 p.m.

### INSTITUTE OF METALS

*Thurs., Feb.* 28.—BIRMINGHAM LOCAL SECTION: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Nickel Alloys with Special Properties in the Field of Physics and Electrical Engineering," C. Gordon Smith, 6.30 p.m.

### INSTITUTE OF PETROLEUM

*Wed., Feb.* 27.—STANLOW BRANCH: Grosvenor Hotel, Chester, "Colour Photography," H. Baines, 7.30 p.m.

### INSTITUTE OF PHYSICS

*Mon., Feb.* 25.—SCOTTISH BRANCH: Natural Philosophy Department, University of Glasgow, "Instrument Transducers," J. Thomson, 7.15 p.m.

*Tues., Feb.* 26.—SCOTTISH BRANCH: Natural Philosophy Department, University of Glasgow, "Instrument Transducers," J. Thomson, 7.15 p.m.

### INSTITUTION OF CHEMICAL ENGINEERS

*Sat., Feb.* 23.—MANCHESTER BRANCH: Reynolds Hall, College of Technology, Manchester, Symposium on "Modern Developments in the Use of Plastics in the Chemical Industry," 2 p.m.

### INSTITUTION OF CIVIL ENGINEERS

*To-day, Feb.* 22.—Grand Hotel, Sheffield, "Recent Developments which Contribute to the Prevention of River Pollution," M. Lovett, 6.15 p.m.

*Mon., Feb.* 25.—Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institutions of Mechanical and Electrical Engineers, Discussion on "Engineering Education in the U.S.S.R.," 5.30 p.m.

*Tues., Feb.* 26.—AIRPORT (B) MEETING: Great George Street, Westminster, London, S.W.1, "The Planning and Design of the New Hong Kong Airport," Henry Grace and J. K. M. Henry, 5.30 p.m.

### INSTITUTION OF ELECTRICAL ENGINEERS

*Mon., Feb.* 25.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Joint Meeting with the Institutions of Mechanical and Civil Engineers, discussion on "Engineering Education in the U.S.S.R.," 5.30 p.m. ★ S. MIDLAND RADIO AND TELECOMMUNICATION GROUP: James Watt Memorial Institute, Great Charles Street, Birmingham, "Recent Trends in the Design and Application of Closed Circuit Television Equipment," I. M. Waters, 6 p.m. ★ N.E. CENTRE: Neville Hall, Newcastle upon Tyne, "Development of Transportable Thermal-Storage Space Heaters," E. Bates; "Electrical Floor Warming," J. W. Moule and W. M. Stevenson, 6.15 p.m. ★ W. UTILIZATION GROUP: Electricity House, Colston Avenue, Bristol, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell, 6 p.m.

*Tues., Feb.* 26.—S. CENTRE: Grand Hotel, Bournemouth, "Age and the Incidence of Fires in Electrical Installations," L. Gosland, 6.30 p.m. ★ MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Discussion on "The Analysis of Waveforms," opened by A. Cooper and D. A. Drew, 5.30 p.m. ★ N.W. SUPPLY GROUP: Engineers' Club, Albert Square, Manchester, "Choice of Insulation and Surge Protection of Overhead Transmission Lines of 33kV and Above," A. Morris Thomas and D. F. Oakeshott, 6.15 p.m.

*Wed., Feb.* 27.—SUPPLY SECTION: Savoy Place, London, W.C.2, "Mechanical Strength of Power Transformers in Service," E. T. Norris, 5.30 p.m. ★ LONDON GRADUATE AND STUDENT SECTION: Visit to General Electric Company, Research Laboratories, Wembley, 2 p.m. ★ S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Electricity in Modern Commercial Horticulture," C. A. Cameron Brown and A. W. Gray, 7 p.m.

*Thurs., Feb.* 28.—Grosvenor House, Park Lane, London, W.1, Annual dinner, 7 p.m. ★ N. MIDLAND CENTRE: Yorkshire Electricity Board, Ferensway, Hull, "Germanium and Silicon Power Rectifiers," T. H. Kinman, G. A. Carrick, R. G. Hibberd and A. J. Blundell, 7.15 p.m.

*Fri., March* 1.—S. CENTRE: South Dorset Technical College, Weymouth, "Analogue Computers," R. Postlethwaite, 6.30 p.m.

### INSTITUTION OF ENGINEERING DESIGNERS

*Thurs., Feb.* 28.—38, Portland Place, London, W.1, "The Practical Application of Production Engineering Research," P. F. Galloway, 6.45 p.m.

### INSTITUTION OF ENGINEERS IN CHARGE

*Wed., Feb.* 27.—E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, Strand, London, W.C.2, "Electric Lamps," A. D. S. Atkinson, 6 p.m.

### INSTITUTION OF ENGINEERS AND SHIPBUILDERS

*Tues., Feb.* 26.—39, Elmbank Crescent, Glasgow, "Paddle Wheel Research," Part III, H. Volpich and I. C. Bridge, 6.30 p.m.

### INSTITUTION OF HEATING AND VENTILATING ENGINEERS

*Tues., Feb.* 26.—SCOTTISH BRANCH: Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2, "Storage of Oil Fuel," T. Chippindale, 7 p.m.

*Wed., Feb.* 27.—LIVERPOOL AND DISTRICT BRANCH: College of Buildings, Clarence Street, Liverpool, "Heat in the Home," G. Braithwaite, 6.30 p.m.

### INSTITUTION OF HIGHWAY ENGINEERS

*Fri., March* 1.—Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Law and Road Safety," J. J. Leeming, 5.30 p.m.

### INSTITUTION OF LOCOMOTIVE ENGINEERS

*Wed., Feb.* 27.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Some Aspects of Locomotive Boiler Feed Water Treatment," A. J. Parsons; and "A Brief History of Locomotive Feed Water Treatment of the London Midland Region of British Railways," J. S. Hancock, 5.30 p.m.

### INSTITUTION OF MECHANICAL ENGINEERS

*To-day, Feb.* 22.—1, Birdcage Walk, Westminster, London, S.W.1, General Meeting, in Conjunction with the Industrial Administration and Engineering Production Group, "Principles and Applications of Spark Machining," D. W. Rudorff, 6 p.m.

*Mon., Feb.* 25.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Joint meeting with the Institutions of Civil and Electrical Engineers, Discussion on "Engineering Education in the U.S.S.R.," 5.30 p.m.

*Tues., Feb.* 26.—STEAM GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Conversion from Coal to Oil Firing," 6.45 p.m. ★ S. WALES BRANCH: S. Wales Institute of Engineers, Cardiff, "The Salvaging of Ships, with particular reference to the 'Empress of Canada,'" W. Colbeck, 6 p.m. ★ BIRMINGHAM A.D. CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Experiences During Forty Years of Automobile Design," A. G. Booth, 6.30 p.m. ★ COVENTRY GRADUATES' SECTION: Craven Arms Hotel, High Street, Coventry, Informal Discussions on "Conception of the British People's Car," and "Is There a Future for Two-Wheelers?" 7.30 p.m.

*Wed., Feb.* 27.—SOUTHERN BRANCH: Cockcroft Hall, Atomic Energy Research Establishment, Harwell, Berks, "Some Wider Aspects of Management," Sir Ewart Smith, 3 p.m. ★ YORKSHIRE BRANCH: Department of Applied Science, Sheffield University, St. George's Square, Sheffield, "A Criticism of the Technical Education of Recently Qualified Engineers," P. P. Love, 6.30 p.m.

*Thurs., Feb.* 28.—INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP: Engineers' Club, Albert Square, Manchester, "Training for Management," L. Landon Goodman, 6.45 p.m. ★ WESTERN A.D. CENTRE: Royal Hotel, Bristol, "Transmission Developments for Public Service and Heavy Goods Vehicles," A. Gordon, 6.45 p.m. ★ E. MIDLANDS GRADUATE SECTION: Technical College, Lincoln, "Some Problems Connected with Marine Gas Turbines," J. E. Wright, 7.15 p.m.

*Fri., March* 1.—HYDRAULICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "Problems in Design of Valves for Liquids," 6.45 p.m. ★ SCOTTISH GRADUATE SECTION: 25, Charlotte Square, Edinburgh, "Manufacture of Transformers," S. A. B. Gray, 7.30 p.m.

### INSTITUTION OF NAVAL ARCHITECTS AND INSTITUTE OF MARINE ENGINEERS

*Tues., Feb.* 26.—SOUTHERN JOINT BRANCH: Portsmouth College of Technology, Portsmouth, "Welded Aluminium Ships' Structures," E. C. B. Corlett, 7.30 p.m.

### INSTITUTION OF PRODUCTION ENGINEERS

*Tues., Feb.* 26.—OXFORD BRANCH: West Oxfordshire Technical College, Witney, Oxford, "Tube Work and Manipulation," L. C. Hackett, 7.30 p.m.

*Wed., Feb.* 27.—WESTERN BRANCH: Small Lecture Theatre, University Engineering Laboratories, University Walk, Bristol, "Automation," S. P. Woodley, 7.15 p.m. ★ SHREWSBURY BRANCH: Technical College, Shrewsbury, "Influence of Production Problems on Modern Machine Tool Design," C. A. Sparkes, 7.30 p.m.

*Thurs., Feb.* 28.—LINCOLN BRANCH: Ruston Club, Lincoln, "Electronic Control," J. A. Stokes, 7.30 p.m.——SOUTHERN BRANCH: Polygon Hotel, Southampton, "Milling versus Broaching," A. R. Hambidge, 7.15 p.m.

*Fri., March* 1.—SOUTHERN BRANCH: Polygon Hotel, Southampton, Annual General Meeting, 7.15 p.m.

*Sat., March* 2.—N.E. GRADUATE SECTION: Visit to Scott Turner, Ltd., Tin Box Factory, Fawdon, Newcastle, 10 a.m.

### INSTITUTION OF THE RUBBER INDUSTRY

*Fri., March* 1.—SOUTHERN SECTION: Civic Centre, Southampton, Joint Meeting with Royal Institute of Chemistry, "Analysis of Accelerators and Antioxidants," C. A. Parker, 8 p.m.

### INSTITUTION OF STRUCTURAL ENGINEERS

*To-day, Feb.* 22.—SCOTTISH BRANCH: Institution of Engineers and Shipbuilders, Glasgow, "Allt-Na-Lairige Prestressed Concrete Dam," J. A. Banks, 7.15 p.m. ★ MIDLANDS COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Revisions to CP114 (1948)," Walter C. Andrews, 6 p.m.

*Thurs., Feb.* 28.—11, Upper Belgrave Street, London, S.W.1, "Factory in Concrete for the Pressed Steel Company, Ltd., Stratton, St. Margaret," D. H. New and R. Sanders, 6 p.m.

*Fri., March* 1.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION: Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, "Handling of Iron Ore in Steel Works," G. F. Wilson, 6.30 p.m. ★ W. COUNTIES BRANCH: University of Bristol, "Some Practical Aspects of Recent Structural Welding Developments," W. H. Diamond, 6 p.m.

### JUNIOR INSTITUTION OF ENGINEERS

*To-day, Feb.* 22.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Soap-making and Finishing Plant," N. J. King, 7 p.m.

*Fri., March* 1.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, Film Evening, 7 p.m.

### LIVERPOOL ENGINEERING SOCIETY

*Wed., Feb.* 27.—24, Dale Street, Liverpool, "Application of Modern Gas Dynamic Theories to Exhaust Systems of I.C. Engines," R. S. Benson, 6 p.m.

### LIVERPOOL METALLURGICAL SOCIETY

*Sat., March* 2.—Liverpool Engineering Society, The Temple, Dale Street, Liverpool, "Conversazione," 7 p.m.

### NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

*To-day, Feb.* 22.—Lecture Theatre, Mining Institute, Newcastle upon Tyne, "Modern Marine Steam-Turbine Feed Systems," A. D. Bonny, 6.15 p.m.

### REINFORCED CONCRETE ASSOCIATION

*To-day, Feb.* 22.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, Joint Meeting with the Institution of Structural Engineers, "The Revision of the Code of Practice for the Use of Normal Reinforced Concrete in Buildings (CP114)," W. C. Andrews, 6 p.m.

### ROYAL AERONAUTICAL SOCIETY

*Tues., Feb.* 26.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Recent Advances in the Design of Aircraft Tyres and Brakes," H. W. Trevaskis, 7 p.m.

### ROYAL SOCIETY OF ARTS

*Mon., Feb.* 25.—CANTER LECTURE: John Adam Street, Adelphi, London, W.C.2, "Lighting in Commerce and Industry," C. Dykes Brown, 6 p.m.

### ROYAL STATISTICAL SOCIETY

*Thurs., Feb.* 28.—LEICESTER GROUP: Leicester College of Technology, The Newarke, Leicester, "Electronics and the Automatic Office," J. C. Masters, 7 p.m. ★ SHEFFIELD GROUP: Grand Hotel, Sheffield, "The Background to a Coal Sampling Specification," R. C. Tomlinson, 7 p.m.

### SOCIETY OF INDUSTRIAL RADIOLOGY

*To-day, Feb.* 22.—Institute of Radiology, 32, Welbeck Street, London, W.1, "Penetrants in Non-Destructive Testing," R. Bentley, 7 p.m.

### SOCIETY OF INSTRUMENT TECHNOLOGY

*Tues., Feb.* 26.—MAIN MEETING: Manson House, Portland Place, London, W.1, "The Determination of Parameters of a Controller by Simple Frequency Measurements," J. H. Westcott, 6.30 p.m.

### WOMEN'S ENGINEERING SOCIETY

*Tues., Feb.* 26.—LONDON BRANCH: Central Electricity Authority, Winsley Street, Nr. Oxford Circus, London, W.1, "Veteran and Vintage Cars," J. Shearman, 7 p.m.